772

A

SYSTEM

OF

CHEMISTRY.

IN FOUR VOLUMES.

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CONTENTS

OF

VOLUME FOURTH.

A

SYSTEM

OF

CHEMISTRY.

BOOK III. OF PART II. CONTINUED.

ORDER III. AGGREGATES.

Class I. Order III.

THIS Order comprehends all mechanical mixtures of earths and stones found in the mineral kingdom. These are exceedingly numerous : the mountains and hills, the mould on which vegetables grow, and indeed the greater part of the globe, may be considered as composed of them. A complete description of aggregates belongs rather to geology than mineralogy. It would be improper, therefore, to treat of them fully here. But they cannot be altogether omitted; because aggregates are the first substances which present themselves to the view of the practical mineralogist; and because, without being acquainted with the names and component parts of many of them, the most valuable mineralogical works could not be understood.

Arrangement.

Aggregates may be comprehended under four divisions: 1. Mixtures of earths; 2. Amorphous fragments of stones agglutinated together; 3. Crystallized stones, either agglutinated together or with amorphous stones; 4. Aggregates formed by fire. It will be exceedingly convenient to treat each of these separately. I shall therefore divide this order into four Sections.

SECT. I.

AGGREGATES OF EARTHS.

The most common earthy aggregates may be comprehended under the following genera:

1. Clay,
2. Colorific earths,
3. Marl,
4 Mould.

Genus I. Clay.

Composition.

Clay is a mixture of alumina and silica in various proportions. The alumina is in the state of an impalpable powder; but the silica is almost always in small grains, large enough to be distinguished by the eye. Clay, therefore, exhibits the character of alumina, and not of silica, even when this last ingredient predominates. The particles of silica are already combined with each other; and they have so strong an affinity for each other, that few bodies can separate them; whereas the alumina, not being combined, readily displays the characters which distinguish it from other bodies. Besides alumina and silica, clay often contains carbonat of lime, of magnesia,

Genus I.
Species I.

barytes, oxide of iron, &c. And as clay is merely a mechanical mixture, the proportion of its ingredients is exceedingly various.

Clay has been divided into the following species:

Sp. 1. Porcelain clay.

Its texture is earthy. Its lustre 0. Opaque. Hardness 4. Specific gravity from 2.23 to 2.4. Colour white, sometimes with a shade of yellow or red. Adheres slightly to the tongue. Feels soft. Falls to powder in water.

A specimen, analysed by Hassenfratz, contained

62 silica
19 alumina
12 magnesia
7 sulphat of barytes

100 *

A specimen, analysed by Mr Wedgewood, contained

60 alumina
20 silica
12 air of water

92

Sp. 2 Common clay

Its texture is earthy. Lustre 0. Opaque. Hardness 3 to 6. Specific gravity 1.8 to 2.68. Adheres slightly to the tongue. Often feels greasy. Falls to powder in water. Colour, when pure, white; often tinged blue or yellow.

Varieties.

Variety 1. Potter's clay.—Hardness 3 to 4. Specific gravity 1.8 to 2. Stains the fingers slightly. Ac-

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* *Ann. de Chim.* xiv. 144.

Class I. Order III.

quires some polish by friction. Colour white; often with a tinge of yellow or blue; sometimes brownish, greenish, reddish. Totally diffusible in water; and, when duly moistened, very ductile.

Variety 2. Indurated clay.—Hardness 5 to 6. Does not diffuse itself in water, but falls to powder. Discovers but little ductility. Colours grey, yellowish, bluish, greenish, reddish, brownish.

Variety 3. Shistose clay.—Structure slaty. Specific gravity from 2.6 to 2.68. Feels smooth. Streak white or grey. Colour commonly bluish, or yellowish grey; sometimes blackish, reddish, greenish. Found in strata, usually in coal mines.

This variety is sometimes impregnated with bitumen. It is then called bituminous *shale*.

Sp. 3. Lithomarga.

Properties.

Texture earthy. Fracture conchoidal. Lustre from 0 to 2. Opaque. Hardness 3 to 7. Specific gravity, when pretty hard, 2.815. Surface smooth, and feels soapy. Adheres strongly to the tongue. Falls to pieces, and then to powder, in water; but does not diffuse itself through that liquid. Fusible *per se* into a frothy mass.

Varieties.

Variety 1. Friable lithomarga.—Formed of scaly particles slightly cohering. Lustre 1 to 0. Hardness 3 to 4. Exceedingly light. Feels very smooth, and assumes a polish from the nail. Colour white; sometimes tinged yellow or red.

Variety 2. Indurated lithomarga.—Hardness 4 to 7. The softer sort adheres very strongly to the tongue when newly broken; the harder very moderately. Colours grey, yellow, red, brown, blue.

Genus I.
Species IV.

Composition.

A specimen of lithomarga, from Osmund, analysed by Bergman, contained

60.0	silica
11.0	alumina
5.7	carbonat of lime
4.7	oxide of iron
0.5	carbonat of magnesia
18.0	water and air
99.9[*]	

Sp. 4. Bole.

Texture earthy. Fracture conchoidal. Lustre 0. Transparency scarce 1. Hardness 4. Specific gravity from 1.4 to 2. Acquires a polish by friction. Scarcely adheres to the tongue. Feels greasy. Colour yellow or brown; sometimes red; sometimes spotted.

Composition.

The lemnian earth which belongs to this species, according to the analysis of Bergman, contains

47.0	silica
19.0	alumina
6.0	carbonat of magnesia
5.4	carbonat of lime
5.4	oxide of iron
17.0	water and air
99.8[†]	

Sp. 5. Fullers earth.

Texture earthy. Structure sometimes slaty. Fracture imperfectly conchoidal. Lustre 0. Opaque. Hardness 4. Receives a polish from friction. Does not adhere to the tongue. Feels greasy. Colour usually light green.

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[*] *Opusc.* iv.

[†] Ibid. p. 157.

Class I. Order III.

Composition.

A specimen from Hampshire, analysed by Bergman, contained . . . . . .

51.8	silica
25.0	alumina
3.3	carbonat of lime
3.7	oxide of iron
0.7	carbonat of magnesia
15.5	moisture
100.0*	

This earth is used by fullers to take the grease out of their cloth before they apply soap. It is essential to fullers earth that the particles of silica be very fine, otherwise they would cut the cloth. Any clay, possessed of this last property, may be considered as *fullers earth*; for it is the alumina alone which acts upon the cloth, on account of its strong affinity for greasy substances.

Genus II. Colorific Earths.

The minerals belonging to this genus consist of clay, mixed with so large a quantity of some colouring ingredient as to render them useful as paints. The colouring matter is commonly oxide of iron, and sometimes charcoal.

Sp. 1. Red chalk—*Reddle.*

Texture earthy. Fracture conchoidal. Lustre 0. Opaque. Hardness 4. Specific gravity inconsiderable. Colour dark red.

Feels rough. Stains the fingers. Adheres to the tongue. Falls to powder in water. Does not become ductile. When heated it becomes black, and at a 159°

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* *Opusc.* iv. 159.

Wedgewood melts into a greenish yellow frothy enamel.

Genus II. Species II.

Composed of clay and oxide of iron.

Sp. 2. Yellow chalk.

Properties.

Texture earthy. Fracture conchoidal. Hardness 3. Specific gravity inconsiderable. Colour ochre yellow.

Feels smooth or greasy. Stains the fingers. Adheres to the tongue. Falls to pieces in water. When heated becomes red; and at 156° Wedgewood melts into a brown porous porcelain.

According to Sage, it contains

Composition.

50	alumina
40	oxide of iron
10	water, with some sulphuric acid
100 *	

Sp. 3. Black chalk.

Properties.

Structure slaty. Texture earthy. Fragments splintery. Lustre 0. Opaque. Hardness 5. Specific gravity 2.144 to 2.77. Colour black. Streak black.

Feels smooth. Adheres slightly to the tongue. Does not moulder in water. When heated to redness it becomes reddish grey.

According to Wiegleb, it is composed of

Composition.

64.50	silica
11.25	alumina
11.00	charcoal.
2.75	oxide of iron
7.50	water
97.00 †	

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[*] *Mem. Par.* 1779. 313.

[†] *Ann. de Chim.* xxx. 13.

Sp. 4. Green earth.

Texture earthy. Lustre 0. Opaque. Hardness 6 to 7. Specific gravity 2.637. Colour green.

Commonly feels smooth. Does not stain the fingers. Often falls to powder in water. When heated it becomes reddish brown; and at 147° Wedgewood melts into a black compact glass.

Composed of clay, oxides of iron and nickel.

GENUS III. MARL.

A mixture of carbonat of lime and clay, in which the carbonat considerably exceeds the other ingredient, is called *marl.*

Its texture is earthy. Lustre 0. Opaque. Hardness from 4 to 8; sometimes in powder. Specific gravity from 1.6 to 2.877. Colour usually grey, often tinged with other colours. Effervesces with acids.

Some marls crumble into powder when exposed to the air; others retain their hardness for many years.

Species. Marls may be divided into two species: 1. Those which contain more silica than alumina; 2. Those which contain more alumina than silica. Mr Kirwan has called the first of these *siliceous*, the second *argillaceous*, marls. Attention should be paid to this distinction when marls are used as a manure.

GENUS IV. MOULD.

By *mould* is meant the soil on which vegetables grow.

Composition. It contains the following ingredients: silica, alumina, lime, magnesia (sometimes), iron, carbon derived from decayed vegetable and animal substances, carbonic acid, and water. And the good or bad qualities of *soils* depend upon a proper mixture of these ingredients. The

Genus IV.
Species I.

silica is seldom in the state of an impalpable powder, but in grains of a greater or smaller size: Its chief use seems to be to keep the soil open and pervious to moisture. If we pass over the carbon, the iron, and the carbonic acid, the goodness of a soil depends upon its being able to retain the quantity of moisture which is proper for the nourishment of vegetables, and no more. Now the retentive power of a soil increases with the proportion of its alumina, lime, or magnesia, and diminishes as the proportion of its silica increases. Hence it follows, that in a dry country, a fertile soil should contain less silica, and more of the other earths, than in a wet country.

Giobert found a fertile soil near Turin, where it rains annually 30 inches, to contain

From	77 to 79	silica
	9 — 14	alumina
	5 — 12	lime.

Near Paris, where it rains about 20 inches annually, Mr Tillet found a fertile soil to contain

Coarse sand	25	46.0	silica
Fine sand	21		
		16.5	alumina
		37.5	lime
		100.0 *	

The varieties of mould are too numerous to admit an accurate description: it will be sufficient, therefore, to mention the most remarkable.

Sp. 1. Sand.

This consists of small grains of siliceous stones not cohering together, nor softened by water. When the grains are of a large size, the soil is called *gravel*.

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* Kirwan *on Manures*.

Class I.
Order III.

Sp. 2. Clay.

This consists of common clay mixed with decayed vegetable and animal substances.

Sp. 3. Loam.

Any soil which does not cohere so strongly as clay, but more strongly than chalk, is called *loam*. There are many varieties of it. The following are the most common.

Variety 1. Clayey loam; called also *strong*, *stiff*, *cold*, and *heavy* loam.—It consists of a mixture of clay and coarse sand.

Variety 2. Chalky loam.—A mixture of clay, chalk, and coarse sand; the chalk predominating.

Variety 3. Sandy loam.—A mixture of the same ingredients; the sand amounting to .8 or .9 of the whole.

Sp. 4. Till.

Till is a mixture of clay and oxide of iron. It is of a red colour, very hard and heavy.

SECT. II.

AGGREGATES OF AMORPHOUS STONES.

THE aggregates which belong to this section consist of amorphous fragments of stones cemented together. They may be reduced to the following genera:

1. Sandstone,
2. Puddingstone,
3. Amygdaloid,
4. Breccia.

Genus I. Species I.

GENUS I. SANDSTONE.

Small grains of sand, consisting of quartz, flint, hornstone, siliceous shistus, or felspar, and sometimes of mica, cemented together, are denominated sandstones. They feel rough and sandy; and when not very hard, easily crumble into sand. The cement or basis by which the grains of sand are united to each other is of four kinds; namely, lime, alumina, silica, iron. Sandstones, therefore, may be divided into four species.

Sp. 1. Calcareous sandstones.

Composition.

Calcareous sandstones are merely carbonat of lime or marl, with a quantity of sand interposed between its particles. Though the quantity of sand, in many cases, far exceeds the lime, calcareous sandstones are sometimes found crystallized: and, in some cases, the crystals, as might be expected, have some of the forms which distinguish carbonat of lime. Thus the calcareous sandstone of Fountainbleau is crystallized in rhomboidal tables. It contains, according to the analysis of Lassone,

62.5	siliceous sand
37.5	carbonat of lime
100.0	

Properties.

Calcareous sandstones have commonly an earthy texture. Their furface is rough. Their hardness from 6 to 7. Their specific gravity about 2.5 or 2.6. Their colour grey; sometimes yellowish or brown. They are sometimes burned for lime.

Sp. 2. Aluminous sandstones.

The basis of argillaceous sandstones is alumina, or rather clay. Their structure is often slaty. Their texture is compact, and either fine or coarse grained, ac-

Class I. Order III.

cording to the size of the sand of which they are chiefly composed. Their hadness is from 6 to 8, or even 9. Their colour is usually grey, yellow, or brown.

They are often formed into mill-stones, filtering-stones, and coarse whet-stones.

Sp. 3. Siliceous sandstones.

Siliceous sandstones consist of grains of sand cemented together by silica, or some substance which consists chiefly of silica or flint. They are much harder than any of the other species.

Sometimes stones occur, consisting of grains of lime cemented together with silica. These stones are also denominated siliceous sandstones.

Sp. 4. Ferruginous sandstones.

The iron which acts as a cement in ferruginous sandstones is not far from a metallic state. When iron is completely oxidated, it loses the property of acting as a cement. This is the reason that ferruginous sandstones, when exposed to the air, almost always crumble into powder.

The colour of ferruginous sandstones is usually dark, red, yellow, or brown. The grains of sand which compose them are often pretty large. Their hardness is commonly inconsiderable.

GENUS II. PUDDING STONE.

Component parts.

Pebbles of quartz, flint, or other similar stones of a round or eliptical form, from the size of rape seed to that of an egg, cemented together by a siliceous cement, often mixed with iron, have been denominated *pudding stones.*

Properties.

Pudding stones, of course, are not inferior in hardness to quartz, flint, chalcedony, &c. of which the peb-

Genus III. Genus IV.

bles may consist. The colour of the cement is usually yellow, brown, or red. Its fracture is conchoidal.

The finer sorts of pudding stones are capable of a fine polish; the coarse are used for mill-stones.

GENUS III. AMYGDALOID.

Component parts.

Rounded or elliptical masses of chalcedony, zeolite, limestone, lithomarga, steatites, green earth, garnets, hornblend, or opal, cemented together by a basis of indurated clay, trap, mullen, walken or kragg, constitute an *amygdaloid.*

Properties.

Amygdaloids are opaque. They have no lustre. Their fracture is uneven or conchoidal. Hardness 6 to 9. Their colours are as various as the ingredients of which they are composed.

GENUS IV. BRECCIA.

Angular fragments of the same *species* of stone agglutinated together, constitute a *breccia.* Thus *calcareous* breccia consists of fragments of marble cemented together by means of lime.

SECT. III.

AGGREGATES OF CRYSTALS.

THE minerals belonging to this Section consist either of crystals of different kinds cemented together, or of crystals and amorphous stones cemented together.

They may be reduced under the following genera.

1. Granite,
2. Sienite,
3. Granatine,
4. Granitell,
5. Granilite,
6. Trap,
7. Porphyry.

GENUS I. GRANITE.

Composition.

An aggregate of felspar, quartz, and mica, whatever be the size or the figure of the ingredients, is denominated *granite*. This aggregate may be divided into two species, namely, *common* granite, and *shistose* granite or gneiss.

Sp. 1. Common granite.

Its structure is always granular. The felspar is often amorphous, and constitutes most frequently the greatest part of the aggregate.

Common granites differ much in their appearance, according to the size, proportion, colour, and figure of their component parts. They are commonly very hard: Their specific gravity varies from 2.5388 to 2.9564.

Sp. 2. Shistose granite or gneiss.

The structure of gneiss is always slaty, and this constitutes its specific character. In gneiss, the proportion of quartz and felspar is nearly equal: the proportion of mica is smallest. It is evidently subject to the same varieties with common granite.

GENUS II. SIENITE.

Composition.

Mr Werner has given the name of *sienite* to aggregates composed of felspar, hornblende, and quartz; or

Genus III.
Genus IV.

of felspar, hornblende, quartz, and mica. These aggregates were formerly confounded with granite.

Sienite is found both of a granular and slaty structure: it might, therefore, like granite, be divided into two species. In sienite the quartz is commonly in by far the smallest proportion.

Genus III. Granatine.

Mr Kirwan has applied the name *granatine* to the following aggregrates.

Composition.

Quartz Felspar Shorl	Quartz Mica Garnet	Quartz Hornblende Jade	Felspar Mica Shorl
Quartz Felspar Jade	Quartz Shorl Hornblende	Quartz Hornblende Garnet	Felspar Mica Hornblende
Quartz Felspar Garnet	Quartz Shorl Jade	Quartz Jade Garnet	Felspar Quartz Serpentine
Quartz Mica Shorl	Quartz Shorl Garnet	Quartz Hornblende Hornstone	Felspar Quartz Steatites
Quartz Mica Jade			

One of these aggregates, namely, *quartz*, *mica*, *garnet*, was called by Cronstedt, *norka* or *murksten*.

Genus IV. Granitell.

Mr Kirwan gives the name of *granitell* to all aggregates composed of any two of the following ingredients: quartz, felspar, mica, shorl, hornblende, jade, garnet, steatites. The most remarkable of these are:

Class I.
Order III.
Composition.

Quartz Felspar	Quartz Hornblende	Quartz Steatites	Felspar Hornblende
Quartz Mica	Quartz Jade	Felspar Mica	Felspar Jade
Quartz Shorl	Quartz Garnet	Felspar Shorl	Felspar Garnet
Mica Shorl	Mica Jade	Hornblende Jade	Jade Garnet
Mica Hornblende	Mica Garnet	Hornblende Garnet	Steatites Shorl

Some of these aggregates have recived particular names. The aggregate of *quartz* and *mica*, when its structure is slaty, is called by Werner *shistose mica*; by the Swedes, it is denominated *stellsten*, whatever be its structure.

The aggregate of hornblende and mica is called *grunstein*, from the dark green colour which it usually has.

GENUS V. GRANILITE.

Under the name of *granilite*, Mr Kirwan comprehends all aggregates containing more than three ingredients. Of these the following are the most remarkable.

Composition.

Quartz Felspar Mica Shorl	Quartz Mica Shorl Garnet	Quartz Sulph. of barytes Mica Shorl
Quartz Felspar Mica Steatites	Quartz Felspar Mica Garnet	Quartz Sulph. of barytes Mica Hornblende

Genus VI. Species I.

GENUS VI. TRAP *.

Under this genus we class not only what has commonly been called *trap*, but also wacken, and mullen, and kragstone of Kirwan.

Sp. 1. Common trap.

This stone is very common in Scotland, and is known by the name of *whinstone*. Whole hills are formed of it: and it occurs very frequently in large rounded detached fragments. Sometimes it assumes the form of immense columns, and is then called *basalt*. The Giants Causeway in Ireland, the island of Staffa, and the south side of Arthur's Seat in Scotland, are well known instances of this figure.

Properties.

Its texture is earthy or compact. Its fracture uneven. Its lustre commonly 0. Opaque. Hardness 8 to 9. Not brittle. Specific gravity from 2.78 to 3.021 †. Colour black, with a shade of grey, blue, or purple; sometimes blackish or reddish brown; in some cases greenish grey. By exposure to the atmosphere, it often becomes invested with a brownish rind. Before the blow-pipe it melts *per se* into a more or less black glass.

Trap consists of small crystals of hornblende, felspar, olivine, &c. usually set in a ground composed apparently of clay and oxide of iron. A specimen, in the form

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* Kirwan, i. 231. and 431.—*Faujas de St Fond. Essai sur l'Hist. Nat. des Roches de Trap.*—*Phil. Trans.* passim.—See also a very ingenious set of experiments on the fusion of trap, by Sir James Hall in *Trans. Edin.* v. 43.

† Kirwan.

Class I.
Order III.

Composition.

of basaltes, from Staffa, analysed by Dr Kennedy of Edinburgh, contained
48 silica
16 alumina
16 oxide of iron
9 lime
5 moisture
4 soda
1 muriatic acid
99*

A specimen from Salisbury rock, near Edinburgh, contained, according to the analysis of the same gentleman . . . .
46.0 silica
19.0 alumina
17.0 oxide of iron
8.0 lime
4.0 moisture
3.5 soda
1.0 muriatic acid
98.5*

Dr Kennedy conducted these analyses with great ingenuity and judgment; and the discovery in which they terminated, that trap contains soda, is certainly of importance, and may lead to valuable consequences both in a geological and mineralogical view.

Sp. 2. Wacken †.

Description.

This stone often forms considerable parts of hills, and, like trap, is amorphous. Its texture is earthy. Its fracture usually even. Lustre 0. Opaque. Hardness

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* *Edin. Trans.* v. 89.

† Ibid. p. 90.

‡ Kirwan, i. 223.

Genus VI. Species III.

6 to 9. Specific gravity from 2.535 to 2.893[*]. Colour grey, with a shade of green, black, red, brown. When exposed to the atmosphere, it withers and becomes more grey.

It melts into a grey porous slag.

Sp. 3. Mullen[†].

Description.

This stone is also found in considerable masses, and sometimes has a tendency to a columnar form like basalt. Texture earthy. Fracture uneven, and fine splintery. Lustre 0, except from some shining particles of basaltine. Opaque. Hardness from 7 to 9. Specific gravity from 2.6 to 2.738. Colour ash or bluish grey; sometimes mixed with ochre yellow, in consequence of the decomposition of the stone. At 130° Wedgewood it melts into a black compact glass.

When mullen is exposed to the air, its surface becomes covered with a greyish white rind, sometimes slightly ochry.

Sp. 4. Kragstone[‡].

This stone, which, like the others, forms considerable parts of rocks, was formed into a distinct species by Mr Kirwan. Its texture is earthy. It is exceedingly porous, and the pores are often filled with the crystals of other minerals. Fracture uneven. Lustre 0. Opaque. Hardness 5 to 7. Specific gravity 2.314. Feels rough and harsh. Colour reddish grey. Streak yellowish grey. At 138° Wedgewood it melts into a reddish brown porcelain mass.

GENUS VII. PORPHYRY.

Any stone which contains scattered crystals or grains

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[*] Kirwan.

[†] Kirwan, i. 225.

[‡] Ibid. p. 226.

Class I. Order III.

Component parts.

of felspar, visible to the naked eye, is denominated a *porphyry* Besides felspar, porphyries generally contain small crystals of quartz, hornblende, and mica. These crystals are usually of a different colour from the stone in which they are found, and they are stuck in it as in a cement. It is evident from this definition, that the number of porphyries must be great. Each species receives its name from the stone which forms its basis. To describe them would be unnecessary. I shall only give a catalogue of the principal species.

Species.

1. Hornstone porphyry,
2. Pitchstone porphyry,
3. Hornslate porphyry,
4. Felspar or petunse porph.
5. Clay porphyry,
6. Hornblende porphyry,
7. Trap porphyry,
8. Wacken porphyry,
9. Mullen porphyry,
10. Krag porphyry,
11. Argillitic porphyry,
12. Potstone porphyry,
13. Serpentine porphyry,
14. Sandstone porphyry.

SECT. IV.

VOLCANIC AGGREGATES *.

AGGREGATES formed by volcanoes may be reduced to the following genera:

1. Lava,
2. Puzzolana,
3. Pumice,
4. Ashes.

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* Dolomieu has published a complete list of all the substances which have been hitherto observed to constitute a part of the matter emitted by burning mountains. See *Jour. de Phys.* xliv. 102.

Genus I.
Species II.

GENUS. I. LAVA.

All substances which have issued out of a volcano in a state of fusion are called *lavas*. They have been divided into three species.

Sp. 1. Vitreous lava.

Found in small pieces. Texture glossy. Fracture conchoidal. Lustre 3. Transparency from 3 to 1. Hardness 9 to 10. Specific gravity from 2 to 3. Colour blackish, greenish, or whitish. Commonly somewhat porous.

Sp. 2. Cellular lava.

This species is full of cells. Surface rough and full of cavities. Texture earthy. Lustre 0. Opaque. Hardness 7 to 9. Specific gravity varies, but does not exceed 2.8. Colour brown or greyish black. Commonly somewhat magnetic.

Sp. 3. Compact lava.

This species is the most common of all; it runs into the second by insensible degrees; and indeed is seldom found of any considerable size without some pores. It bears in general a very strong resemblance to trap.

Composition.

A specimen of the lava of Catania in Sicily, analysed by Dr Kennedy, contained

51.0	silica
19.0	alumina
14.5	oxide of iron
9.5	lime
4.0	soda
1.0	muriatic acid
99.0 *	

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* Trans. Edin. v. 93.

Class I.
Order III.

A specimen of the lava of Sta. Venere in Sicily he found to contain . .

50.75	silica
17.50	alumina
14.25	oxide of iron
10.00	lime
4.00	soda
1.00	muriatic acid
97.5 [*]	

Thus we see that the resemblance betwee trap and lava holds not only in their external appearance, but also in their component parts.

Genus II. Puzzolana.

Found in small pieces. Surface rough. Texture earthy and porous. Fracture uneven. Lustre 0. Opaque. Hardness 3. Very brittle. Specific gravity from 2.57 to 2.8. Colour brown or dark grey. Magnetic. Easily melts into a black slag.

When mixed with lime into a mortar, it possesses the property of hardening even under water. This property it owes most probably, as Mr Kirwan supposes, to the iron which it contains. The iron decomposes the water of the mortar; and thus, in a very short time, renders it too hard to be acted on by water.

Genus III. Pumice.

This is a very light substance ejected from volcanoes. It is porous. Hardness 3. Brittle. Specific gravity below 1. Colour grey or brown.

In some varieties the lustre and transparency are 0: in others, the lustre is glassy, 2. Transparency from 1 to 2.

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[*] *Edin. Trans.* v. 94.

GENUS IV. VOLCANIC ASHES.

These are analogous to the ashes of common pitcoal. Loose and smooth, very light, and fine. Slowly diffusible in water, and when wet somewhat ductile.

APPENDIX.

OF MOUNTAINS.

THE mountains, which constitute so conspicuous a part of the earth's surface, are chiefly composed of the aggregates which have been just described.

Mountains, by Werner and his disciples, are divided into four classes; namely,

1. Primitive, 3. Secondary,
2. Intermediate, 4. Tertiary.

To which may be added volcanic mountains as a fifth class.

I. Primitive mountains are composed of the following substances:

1. Granite, 7. Porphyry,
2. Gneiss, 8. Sienite,
3. Micaceous shistus, 9. Serpentine,
4. Argillaceous shistus, 10. Topaz rock,
5. Primitive limestone, 11. Quartz,
6. Trap, 12. Siliceous shistus.

II. Intermediate mountains are composed of,

1. Limestone, 3. Amygdaloid,
2. Trap, 4. Wacken.

Class I.
Order III.

III. Secondary mountains are composed of

1. Sandstone,
2. Limestone,
3. Gypsum,
4. Chalk,
5. Coal,
6. Common salt,
7. Argillaceous iron stone and calamine,
8. Trap.

Under the name of *trap* Werner includes, 1. Wacken; 2. Basalt; 3. Shistose porphyry; 4. Granite; 5. Amygdaloid; 6. Grausten; 7. Argillaceous tufa or decomposed wacken.

IV. Tertiary mountains are composed of

1. Sand and pebbles,
2. Clays and mud,
3. Bituminous tufa.

CLASS II.

SALTS.

UNDER this Class I comprehend all the combinations of alkalies with acids which exist in the mineral kingdom. They constitute the following genera and species.

Division.

GENUS I. POTASS.

Sp. 1. Sulphat of potass,
2. Nitrat of potass.

GENUS II. SODA.

Sp. 1. Carbonat of soda,
2. Sulphat of soda,
3. Muriat of soda,
4. Borax.

GENUS III. AMMONIA.

Sp. 1. Sulphat of ammonia,
2. Muriat of ammonia.

But of these species there are scarcely more than two which properly belong to the mineral kingdom; namely, carbonat of soda, and common salt. The rest are almost always in a state of solution, and therefore belong to *mineral waters*.

Carbonat of soda.

I. Carbonat of soda is deposited in large masses in different countries under the surface of the earth, and is usually mixed with common salt, and probably also with lime. It has often the appearance of a rough dusty powder, of a grey colour and alkaline taste. It occurs in China, where it is called *kien;* near Tripoli, where it is denominated *trona;* and likewise in Hungary, Syria, Egypt, Persia, and India *.

Common salt.

II. Common salt is found in immense masses under the earth's surface in many countries, particularly in Poland, Hungary, England, &c. Near Cordova in Spain there is said to be a mountain of common salt 500 feet high, and nearly three miles in circumference. There are two varieties of native common salt distinguished by their texture.

Varieties.

1. Foliated. This variety is usually found in vast masses, and sometimes crystallized in cubes. Colour various shades of grey and of red. Internal lustre glassy, 2 to 3. Transparency 2 to 4. Texture foliated. Fragments cubic. Streak grey. Hardness 4 to 5, sometimes 8. Specific gravity 2.143. Taste salt.

2. Fibrous. Found in masses, strata, or stalactitic. Colour various shades of grey, blue, red. Lustre 2. Transparency 3 to 4. Texture fibrous: fibres delicately curved. Fragments angular. Hardness 5 †.

For a more complete description of these, and the remaining species belonging to this Class, the reader is referred to Book II. Division II. Chap. III. of this Work.

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* Kirwan's *Min.* ii. 6.

† Ibid. p. 31.

Genus I.
Species I.

CLASS III.

COMBUSTIBLES.

THE combustible substances belonging to the mineral kingdom, excluding the metals, may be comprehended under the following genera. Genera.

1. Sulphur,
2. Carbon,
3. Bitumen,
4. Coal,
5. Amber.

GENUS I. SULPHUR.

Sp. 1, Native sulphur.

This substance is found abundantly in many parts of the world, especially near volcanoes, as Hecla, Ætna, Vesuvius, the Lipari islands, &c. It is either in the state of powder, or massive, or crystallized. The primitive form of its crystals is an octahedron, composed of two four-sided pyramids, joined base to base. The sides of these pyramids are scalene triangles, and so inclined that the plane where the bases of the pyramids join is a rhomb, whose long diagonal is to its short as 5 to 4 *. Sometimes the apices of the pyramids, to use the language of Romé de Lisle, are truncated; some- Crystals.

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* Romé de Lisle, i. 292.—Hauy and Lefroy, *Jour. de Min.* No. xxix. 337.

times they are separated from each other by a prism; sometimes they are truncated near their bases, and a low four-sided pyramid rises from the truncature: this pyramid is also sometimes truncated near its apex. Finally, one of the edges of the pyramids is sometimes truncated. For figures of these varieties, and for the laws of their formation, the reader is referred to Mr Lefroy*.

Properties. Colour yellow, with a shade of green; sometimes reddish †. Lustre greasy, 2. Transparency varies from 0 to 4. Causes double refraction ‡. Texture compact. Hardness 4 to 5. Brittle. Its other properties have been formerly detailed.

Sometimes sulphur is mixed with different proportions of earths. These combinations are hardly susceptible of accurate description.

Sulphur combines also with metals. These combinations shall be described in the Fourth Class.

Genus II. Carbon.

This genus comprehends all minerals composed of pure carbon, or of carbon combined with a little earth.

Sp. 1. Diamond.

This mineral, which was well known to the ancients, is found in different parts of Asia, particularly in the kingdoms of Golconda and Visapour; it is found also in Brazil.

Crystals. It is always crystallized; but sometimes so imperfectly, that at the first sight it might pass for amorphous. Its primitive form is a regular octagon; but

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* *Jour. de Min.* No. xxix. 337.

† It then contains arsenic.

‡ Hauy.

it more commonly assumes a spheroidal form; and then has usually 36 curvilinear triangular faces, six of which are raised upon each of the faces of the primitive octagon. Its integrant molecule, according to Hauy, is a regular tetrahedron.—For a more particular account of the crystals of this mineral, the reader is referred to Romé De Lisle* and Mr Hauy†.

Properties.

Texture foliated. Lustre 4. Transparency from 2 to 4. Causes single refraction. Hardness 20. Specific gravity 3.5185 to 3.5310‡. Colour various; sometimes limpid, sometimes red, orange, yellow, green, blue, and even blackish.

When rubbed it becomes positively electric, even before it has been cut by the lapidary, which is not the case with any other gem §.

It is composed of pure carbon ||.

Sp. 2. Mineral charcoal.

Kilkenny coal—Wales culm.

This mineral has been found in Hungary, Italy, France, Ireland, and Wales. It occurs in stratified masses, or in lumps nested in clay.

Properties.

Colour black. Lustre 4, metallic. Opaque. Texture foliated. Hardness 5 to 7. Specific gravity 1.4 to 1.526. Often stains the fingers. Insoluble in acids. Defiagrates with nitre. Does not burn till wholly ignited, and then consumes slowly without emitting flame or smoke.

It consists almost entirely of *charcoal*, which, as Morveau has proved, is an oxide of carbon ¶.

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* *Crystallog.* ii. 191.

† *Jour. de Min.* No. xxix. 343.

‡ Hauy, Ibid.

§ Ibid.

|| Morveau, *Ann. de Chim.* xxxi. 72.

¶ Ibid.

Sp. 3. Anthracite*.

Anthracolite of Born.

This substance, as Dolomieu informs us, is found exclusively in the primitive mountains. It is commonly amorphous, sometimes crystallized in short hexagonal prisms. Colour black or brownish black. Lustre 3 to 4. Structure slaty. Fragments rhomboidal. Hardness 6 to 7. Specific gravity 1.300. Often stains the fingers.

Burns precisely like the last species, and leaves .40 of white ashes. According to Dolomieu, it is composed of about . . . . . 64.0 charcoal
32.5 silica
3.5 iron

100.0†

It is probable that the charcoal in the two last substances is in the same state in which it exists in plumbago, combined with oxygen, but not containing so much as charcoal does‡.

GENUS III. BITUMEN.

By bitumen is understood, by mineralogists in general, an oil which is found in different parts of the earth, in various states of consistence. These different states form distinct species; in the arrangement of which I shall be guided by the observations which Mr Hatchett has made in his valuable paper on bituminous substances§.

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[*] This name was given by Hauy from *ανθραξ*, *a coal*. See Delametherie, *Jour. de Phys.* xlvi. 50.

[†] *Jour. de Min.* xxix. 338.

[‡] Morveau, Ibid.

[§] Nicholson's *Journal*, ii. 201, 248.

Sp. 1. Naphtha.

Genus III. Species I.

This substance is found sometimes on the surface of the water of springs, and sometimes issuing from certain strata. It is found in great abundance in Persia.

Properties.

It is as fluid and transparent as water. Colour white or yellowish white. Smell strong, but not disagreeable. Specific gravity when white, .708[*] or .729[†]; when yellowish, .8475[‡]. Feels greasy. Catches fire on the approach of flame, burns with a white flame, and leaves scarce any residuum.

Insoluble in alcohol. Does not freeze at 0° Fahrenheit. When pure naphtha is exposed to the air, it becomes yellow and then brown; its consistence is increased, and it passes into *petroleum*[§].

Sp. 2. Petroleum.

Where found.

This substance is also found in Persia, and likewise in many countries in Europe, particularly Italy, France, Switzerland, Germany, Sweden, England, and Scotland.

Properties.

Not so fluid nor transparent as water. Colour yellow, either pale or with a shade of red or green; reddish brown and reddish black. Smell that of naphtha, but less pleasant. Specific gravity .8783[‖]. When burned it yields a soot, and leaves a small quantity of coally residuum.

By exposure to the air it becomes like tar, and is then called *mineral tar*[¶].

Sp. 3. Mineral tar.

This substance is found in many parts of Asia, America, and Europe. It is viscid, and of a black, brown-

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[*] Mussenbroek.
[†] Boulduc.
[‡] Brisson.
[§] Hatchett.
[‖] Brisson.
[¶] Hatchett, Nicholson's *Journal*, 201, 248.

Class III. ish black, or reddish colour. Smell sometimes strong, but often faint. Specific gravity 1.1. When burned, emits a disagreeable bituminous smell. By exposure to the air it passes into *mineral pitch* and *maltha* *.

Sp. 4. Mineral pitch and maltha.

Properties. This substance has a strong resemblance to common pitch. When the weather is warm it is soft, and has some tenacity; it is then called *adhesive mineral pitch*: when the weather is cold it is brittle; its hardness is 5; and its fracture has a glassy lustre. In this state it is called *maltha*. Colour black, dark brown, or reddish. Lustre 0. Opaque. Specific gravity from 1.45 to 2.07. Does not stain the fingers. On a white hot iron it flames with a strong smell, and leaves a quantity of grey ashes. It is to the presence of the earths which compose these ashes that the great specific gravity of this bitumen is to be ascribed. By farther induration it passes into *asphalt*.

Sp. 5. Asphalt.

This substance is found abundantly in many part of Europe, Asia, and America, especially in the island of Trinidad.

Properties. Colour black or brownish black. Lustre greasy 2. Opaque. Fracture conchoidal, of a glassy lustre. Hardness from 7 to 8. Very brittle. Specific gravity 1.07 to 1.165 †. Feels smooth, but not greasy. Does not stain the fingers. Has little or no smell, unless when rubbed or heated. When heated, melts, smells, and inflames; and when pure, burns without leaving any ashes.

Asphalt is manufactured in France, and used for greasing the wheels of carriages ‡.

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* Hatchett, *Nicholson's Journal*, ii. 201, 248.

† Kirwan.

‡ *Jour. de Min.*, No. xiii. 33.

Genus III.
Species VI.

Sp. 6. Elastic bitumen.

Mineral caoutchouc.

This substance was found about the year 1786 in the lead mine of Odin, near Castletown, Derbyshire. It was first mentioned by Mr De Born.

Properties.

Colour yellowish or reddish brown, sometimes blackish brown. In its appearance it has a strong resemblance to caoutchouc or Indian rubber; hence its name. Consistency various: sometimes so soft as to adhere to the fingers; sometimes nearly as hard as asphalt. When soft it is elastic; when hard brittle. Specific gravity 0.9053 to 1.0233 *.

Insoluble in alcohol, ether, and oil of turpentine, but soluble in oil of olives. Not affected by nitric acid. When distilled it yields a bituminous oil insoluble in alcohol; the residuum is carbonaceous †.

Variety.

There is a variety of this substance found in a rivulet near the mine of Odin, which, when fresh cut, exactly resembles fine cork in colour and texture; but in a few days after being exposed to the air, becomes of a pale reddish brown. This substance contains within it a nucleus of elastic bitumen. It seems to be the elastic bitumen altered in its texture by the water ‡.

GENUS IV. COAL.

The substances belonging to this genus are composed of carbon or rather charcoal, and bitumen.

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* Hatchett, Nicholson's *Journal*, ii. 201. 248.

† Lametherie, *Jour. de Phys.* xxxi. 312.

‡ Hatchett, Nicholson's *Journal*, ii. 201. 248.

Class III.

Sp. 1. Jet *.

This substance is found in France, Spain, Germany, Britain, and other countries. It is found in detached kidneyform masses, of various sizes, from an inch to seven or eight feet in length.

Properties.

Colour full black. Lustre 3 to 4; internal glassy. Opaque. Hardness 7 to 8. Not near so brittle as asphalt. Texture striated. Fracture conchoidal. Specific gravity 1.259 †. It has no odour except when heated, and then it resembles asphaltum in its odour. Melts in a strong heat, burns with a greenish flame, and leaves an earthy residuum ‡.

Becomes somewhat electric by friction §. When distilled yields a peculiar acid ||.

Uses.

This mineral is formed into buttons, beads, and othe trinkets. The manufacture has been almost confine to France ¶.

Sp. 2. Cannel coal.

This mineral is found in Lancashire, and in differen parts of Scotland, where it is known by the name *parrot coal.*

Properties.

Colour black. Lustre common, 2. Opaque. Stru ture sometimes slaty. Texture compact. Fracture co choidal. Hardness 5 to 8. Brittle. Specific grav 1.232 to 1.426. Does not stain the fingers.

Kindles easily, and burns with a bright white fla like a candle * *, which lasts but a short time. It d not cake. It leaves a stony or sooty residuum.

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[*] It was called *gagathes* by the ancients, from the river Gages in L near which it was found; *jayet* in French, *ozalache* in Spanish, *gaga* German.

[†] Brisson. [‡] Hatchett. [§] Kirwan. [||] Vauqueli

[¶] *Jour. de Min* No. iv. 41.

[* *] Hence it has been called *cannel coal.* *Candle,* in the Lanca and Scotch dialect, is pronounced *cannel.*

Genus IV.
Species III.

Composition.

A specimen of Lancashire cannel coal, analysed by Mr Kirwan, contained 75.20 charcoal
21.68 maltha
3.10 alumina and silica

99.98 *

A specimen of the slaty kind from Airshire, called *splent coal*, was composed of 47.62 charcoal
32.52 maltha
20.00 earths

100.14 †

Cannel coal is susceptible of polish, and, like jet, is often wrought into trinkets.

Sp. 3. Common coal.

This very useful combustible is never found in the primitive mountains, but only in the secondary mountains, or in plains formed of the same materials with them. It is always in strata, and generally alternates with clay, sandstone, or limestone.

Properties.

Colour black, more or less perfect. Lustre usually greasy or metallic, 2 to 4. Opaque. Structure generally slaty. Texture often foliated. Fracture various. Hardness 4 to 6. Specific gravity 1.25 to 1.37. Usually stains the fingers. Takes fire more slowly, and burns longer, than the last species. Cakes more or less during combustion.

Varieties.

Of this species there are many varieties, distinguished in Britain by the names of caking coal, rock coal, &c. These are too well known to require any description.

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* *Mineral.* ii. 523.

† Ibid. 524.

Class III.

Mr Kirwan analysed a variety of different kinds of coal. The result of his experiments may be seen by the following table:

Composition.

Whitehaven coal.	Wigan.	Swansey.	Leitrim.	
57.0	61.73	73.53	71.43	charcoal.
41.3	36.7	23.14	23.37	maltha & asph.
1.7	1.57	3.33	5.20	earths *.
100.0	100.00	100.00	100.00	

Sp. 4. Spurious coal.

This mineral is generally found amidst strata of genuine coal. It is also called *parrot coal* in Scotland.

Colour greyish black. Lustre 0 to 1. Structure usually slaty. Texture earthy. Hardness 7 to 8. Specific gravity 1.5 to 1.6. Generally explodes, and bursts when heated.

Composed of charcoal, maltha, and asphalt, and above .20 of stony matter.

GENUS V. AMBER.

Sp. 1. Common amber.

This substance, called *electrum* by the ancients, i found in different countries; but most abundantly i Prussia, either on the sea-shore, or under ground at th depth of about 100 feet, reposing on *wood coal* †. is in lumps of different sizes.

Properties

Colour yellow. Lustre 3 to 2. Transparency 2 to Fracture conchoidal. Hardness 5 to 6. Specific gravi 1.078 to 1.085. Becomes electric by friction.

If a piece of amber be fixed upon the point of knife, and then kindled, it burns to the end witho melting ‡.

By distillation it yields succinic acid.

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* *Mineral.* ii. 525.

† Kirwan, *Min.* ii. 66.

‡ Hauy.

CLASS IV.

METALLIC ORES.

Class IV.

THIS class comprehends all the mineral bodies, composed either entirely of metals, or of which metals constitute the most considerable and important part. It is from the minerals belonging to this class that all metals are extracted; for this reason they have obtained the name of *ores*.

As the metals at present known amount to 21, I shall divide this class into 21 orders, allotting a distinct order for the ores of every particular metal.

Metals found in four states.

Metals exist in ores in one or other of the four following states. 1. In a metallic state, and either solitary or combined with each other. 2. Combined with sulphur. 3. In the state of oxides. 4. Combined with acids. Each order therefore may be divided into the four following genera.

1. Alloys.	3. Oxides.
2. Sulphurets.	4. Salts.

It must be observed, however, that every metal has not hitherto been found in all these four states, and that some of them are hardly susceptible of them all. Some of the orders therefore want one or more genera, as may be seen from the following Table.

Class IV.
Table of the orders and genera.

Order I. *Gold ores.*
1. Alloys.

Order II. *Platinum ores.*
1. Alloys.

Order III. *Silver ores.*
1. Alloys.
2. Sulphurets.
3. Oxides.
4. Salts.

Order IV. *Ores of mercury.*
1. Alloys.
2. Sulphurets.
3. Oxides.
4. Salts.

Order V. *Copper ores.*
1. Alloys.
2. Sulphurets.
3. Oxides.
4. Salts.

Order VI. *Iron ores.*
1. Alloys.
2. Sulphurets.
3. Carburets.
4. Silicated iron.
5. Oxides.
6. Salts.

Order VII. *Tin ores.*
1. Sulphurets.
2. Oxides.

Order VIII. *Lead ores.*
1. Sulphurets.
2. Oxides.
3. Salts.

Order IX. *Nickel ores.*
1. Sulphurets.
2. Oxides.
3. Salts.

Order X. *Zinc ores.*
1. Sulphurets.
2. Oxides.
3. Salts.

Order XI. *Antim. ores.*
1. Alloys.
2. Sulphurets.
3. Oxides.
4. Salts.

Order XII. *Bismuth ores.*
1. Alloys.
2. Sulphurets.
3. Oxides.

Order XIII. *Tellurium ores.*
1. Alloys.

Order XIV. *Arsenic ores.*
1. Alloys.
2. Sulphurets.
3. Oxides.

Order XV. *Cobalt ores.*
1. Alloys.
2. Sulphurets.
3. Oxides.
4. Salts.

Order XVI. *Manganese ores.*
1. Oxides.
2. Salts.

ORDER XVII. *Tungsten ores.*
1. Oxides.
ORDER XVIII. *Molybdenum ores.*
1. Sulphurets.
ORDER XIX. *Uranium ores.*
1. Oxides.
ORDER XX. *Titanium ores.*
1. Oxides.
ORDER XXI. *Chromum ores.*
1. Oxides.

ORDER I. ORES OF GOLD.

Where found.

No metal perhaps, if we except iron, is more widely scattered through the mineral kingdom than gold[*]. Hitherto it has been found only in a metallic state; most commonly in grains, ramifications, leaves, or rhomboidal, octahedral, or pyramidal chrystals. It is generally mixed with quartz, though there are instances of its having occurred in calcareous rocks. It is not uncommon also to find it disseminated through the ores of other metals; especially iron, mercury, copper, and zinc. The greatest quantity of gold is found in the warmer regions of the earth. It abounds in the sands of many African rivers, and is very common in South America and India. Europe, however, is not destitute of this metal. Spain was famous in ancient times for its gold mines, and several of the rivers in France contain it in their sands[†]. But the principal gold mines in Europe are those of Hungary, and next to them those of Saltzburg. Gold also has been discovered in Sweden and Norway, and more lately in the county of Wicklow in Ireland[‡].

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[*] Bergman.

[†] Reaumur, *Mem. Par.* 1718, p. 68.

[‡] Lloyd, *Phil. Trans.* 1796, p. 36. Mills, Ibid. p. 38.—Nicholson's *Journal*, ii. 224.

GENUS I. ALLOYS OF GOLD.

Sp. 1. Native gold.

Native gold is never completely pure; it is alloyed with some silver or copper, and sometimes with iron. In the native gold found in Ireland, indeed, the quantity of alloy appears to have been exceedingly small.

Properties. Its colour is yellow. Lustre metallic. Fracture hackly. Hardness 5. Specific gravity from 12 to 19.

ORDER II. ORES OF PLATINUM[*].

Situation. HITHERTO no mine of platinum has been discovered. It is found in small scales or grains in the sands of the river Pinto, at Choco, Popayen and Quito in Peru, and near Carthagena in South America. It is always in a metallic state, and always combined with iron.

GENUS I. ALLOYS OF PLATINUM.

Sp. 1. Native platinum.

Platina.

Properties. Its colour is whitish iron grey. Magnetic. Specific gravity from 12 to 16. Soluble in nitro-muriatic and oxy-muriatic acids.

Composition. Mr Proust has proved that this mineral, besides platinum and iron, contains also copper, plumbago, sulphur, and phosphorus.

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[*] See Brownrigg, *Phil. Trans.* xlvi. 584.—Lewis, Ibid. xlviii. 638. and l. 148.—Margraf, *Mem. Berlin*, 1757, p. 314.—Macquer, *Mem. Par.* 1758, p. 119.—Buffon, *Jour. de Phys.* iii. 324.—Morveau, Ibid. vi. 193.—Bergman, *Opusc.* ii. 166.—Tillet, *Mem. Par.* 1779, p. 373. and 385. and 545.—Crell, Crell's *Annals*, 1784, 1 Band. 328.—Willis, *Manchester Memoirs*, iii. 467.—Mussin Puschkin, *Ann. de Chim.* xxiv. 205.—Morveau, Ibid. xxv. 3.—Proust, Ibid. xxxviii. 146.

Genus I. Species I.

ORDER III. ORES OF SILVER.

Situation.

SILVER is found most commonly in quartz, limestone, hornstone; or combined with the ores of other metals, most commonly with copper, antimony, zinc, cobalt, and lead. This last metal indeed is seldom totally destitute of silver.

GENUS I. ALLOYS OF SILVER.

Sp. 1. Native silver *.

Forms.

Native silver, so called because the silver is nearly in a state of purity, forms the principal part of some of the richest silver mines in the world. It is sometimes in small lumps; sometimes crystallized in cubes, hexahedrons, octahedrons, or dodecahedrons; sometimes in leaves, or threads, often so connected with each other as to resemble branches of trees, and therefore called *dendrites*. The silver in the famous mines of Potosi has this last form. When newly extracted, it is not unlike small branches of fir †.

Properties.

The colour of native silver is white; often tarnished. Lustre metallic. Fracture hackly. Hardness 6. Malleable. Specific gravity from 10 to 10.338.

The silver in this species is almost constantly alloyed with from .03 to .05 of some other metal, frequently gold or arsenic.

Sp. 2. Alloy of silver and gold.

Auriferous native silver.

This alloy is not uncommon in silver mines. Its colour is yellowish white. Its lustre metallic. Hardness 5.

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[*] Kirwan, ii. 108.—*Calling. Act. Liter. Sveciæ*, 1738, p. 420.

[†] Bergman's *Phys. Geogr.*—*Jour. de Min.* No. xvi. p. 26.

Class III. Order III.

Malleable. Specific gravity above 10.6. Dr Fordyce found a specimen from Norway composed of

72 silver
28 gold

100[*]

Sp. 3. Alloy of silver and antimony[†].

Antimoniated silver ore.

This alloy, which is found in the silver mines of Spain and Germany, is sometimes in grains or lumps, and sometimes crystallized in six-sided prisms, whose sides are longitudinally channelled[‡].

Properties.

Its colour is white. Its lustre metallic. Hardness 10. Brittle. Specific gravity from 9.4406[§] to 10[‖]. Texture foliated. Fracture conchoidal. Before the blow-pipe the antimony evaporates in a grey smoke, and leaves a brownish slag, which tinges borax green. If borax be used at first, a silver bead may be obtained.

This alloy was long supposed to contain arsenic. Bergman examined it, and found only silver and antimony[¶]. His analysis has been confirmed by the experiments of Vauquelin and Selb[**]. According to Selb,

Composition.

it is composed of . . 89 silver
11 antimony

100

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[*] *Phil. Trans.* 1776, p. 532.

[†] Kirwan, ii. 110.

[‡] Romé de Lisle, iii. 461.

[§] Hauy, *Jour de Min.* No. xxx. 473.

[‖] Kirwan, ii. 110.

[¶] *Opusc.* ii. 415.

[**] *Jour. de Min.* No. xxx. 473.

A specimen, analysed by Klaproth, contained

84	silver
16	antimony
100	

Another specimen contained

76	silver
24	antimony
100*	

GENUS II. SULPHURETS OF SILVER.

Sp. 1. Common sulphuret of silver†.

Vitreous silver ore.

This ore occurs in the silver mines of Germany and Hungary. It is sometimes in masses, sometimes in threads, and sometimes crystallized. Its crystals are either cubes or regular octahedrons, whose angles and edges are often variously truncated. For a description of the varieties produced by these truncatures, the reader is referred to Romé de Lisle‡.

Crystals.

Its colour is dark bluish grey, inclining to black; often tarnished. Internal lustre metallic. Texture foliated. Fracture uneven. Hardness 4 to 5. May be cut with a knife like lead. Flexible and malleable. Specific gravity 6.909§ to 7.215‖. In a gentle heat the sulphur evaporates. Melts when heated to redness.

Properties.

A specimen of this ore, analysed by Klaproth, contained . . . . 85 silver
15 sulphur
100¶

Composition.

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* Beitrage, ii. 301.
† Kirwan, ii. 115.
‡ *Crystal.* iii. 44.
§ Brisson.
‖ Gellert.
¶ Beitrage, i. 162.

Sp. 2. Antimoniated sulphuret of silver*.

Sulphuret of silver with antimony and iron.

This ore, which occurs in Saxony and Hungary, seems to be sulphuret of silver contaminated with antimony and iron, and ought therefore, in all probability, to be considered merely as a variety of the last species. It is sometimes in masses, but more frequently crystallized in six-sided prisms, tables, or rhomboids; generally indistinct and accumulated together.

Properties.

Its colour is iron grey; often tarnished. Its lustre metallic. Fracture uneven. Hardness 4 to 5. Brittle. Specific gravity 7.208†. Before the blow-pipe the sulphur and antimony exhale, leaving a bead, which may be freed from iron by fusion with nitre and borax.

Composition.

A specimen of this ore, analysed by Klaproth, contained . . . . . . 66.5 silver
12.0 sulphur
10.0 antimony
5.0 iron
1.0 silica
0.5 arsenic and copper
95.0‡

Sp. 3. Sulphuret of silver and copper §.

Cupriferous sulphurated silver ore.

This ore, which is found in the Korbolokinsk mountains in Siberia, was first described by Mr Renovantz. It is in amorphous masses, varying in size from that of the thumb to that of the fist.

Its colour is bluish grey like lead. Lustre metallic.

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* Kirwan, ii. 118.

† Gellert.

‡ Beitrage, i. 166.

§ Kirwan, ii. 121.

Genus III. Species I.

Hardness 5 to 6. Brittle. Its powder, when rubbed on the skin, gives it a black colour and a leaden gloss. Before the blow-pipe the sulphuret of silver melts readily; that of copper with difficulty. This ore is composed of about

Composition.

42 silver
21 copper
35 sulphur
98

GENUS III. OXIDES OF SILVER.

Sp. 1. Calciform silver ore*

This ore was first described by Mr Widenman. It is sometimes in masses, sometimes disseminated through other minerals.

Its colour is greyish black. Its streak bright. Its lustre metallic. Its fracture uneven. Hardness 4 to 5. Brittle. Specific gravity considerable. Effervesces with acids. Melts easily before the blow-pipe. Froths with borax.

According to Selb, it contains

Composition.

72.5 silver
15.5 antimony
12.0 carbonic acid
100.0 and a little copper

Sp. 2. Red silver ore†.

This ore is very common in several German silver

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* Kirwan, ii. 112.

† Kirwan, ii. 122.—Scopoli *de Minera Argenti Rubra.*—Sage, *Jour. de Phys.* xxxiv. 331. and xli. 370.; and *Nouv. Jour. de Phys.* ii. 284.—Westrum, *Jour. de Phys.* xliii. 291.—Klaproth, *Beitrage*, i. 141.

Crystals.

mines. It occurs in masses, disseminated and crystallized. The primitive form of its crystals is a dodecahedron, whose sides are equal rhombs, and which may be considered as a six-sided rhomboidal prism, terminated by three-sided summits[*]. Sometimes the prism is lengthened, and sometimes its edges, or those of the terminating summit, or both, are wanting. For a description and figure of these varieties, the reader is referred to De Lisle[†] and Hauy[‡].

Properties.

Its colour is commonly red. Streak red. External lustre metallic, internal common. Transparency from 3 to 1; sometimes opaque. Fracture flat conchoidal. Hardness 5 to 7. Brittle. Specific gravity from 5.44[§] to 5.592[||]. Becomes electric by friction, but only when insulated[¶]. Soluble in nitric acid without effervescence[**]. Before the blow-pipe melts, blackens, burns with a blue flame, gives out a white smoke with a slight garlic smell, and leaves a silver bead[††].

Varieties.

Variety 1. Light red.—Colour intermediate between blood and cochineal red; sometimes variegated. Streak orange red. Powder black.

Variety 2. Dark red.—Colour commonly between dark cochineal red and lead grey; sometimes nearly black and without any shade of red. Streak dark crimson red.

This ore was long supposed to contain arsenic. Klaproth first ascertained its real composition[‡‡]; and his

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[*] Romé de Lisle, iii. 447.

[†] Ibid.

[‡] *Jour. d'Hist. Nat.* No. xviii. p. 216.

[§] Kirwan.

[||] Vauquelin, *Jour. de Min.* xvii. 2.

[¶] Hauy, Ibid. xxx. 476.

[**] Hauy, Ibid. xxxi 518.

[††] Vauquelin, Ibid.

[‡‡] *Ann. de Chim.* xviii. 81.

Genus IV. Species I.

analysis has been confirmed by Vauquelin, who found a specimen composed of 56.6748 silver

Composition.

16.1300 antimony
15.0666 sulphur
12.1286 oxygen

100.

Klaproth proved that the silver and antimony are in the state of oxides; and Vauquelin, that the sulphur is combined partly with the oxide of silver and partly with the oxide of antimony. Klaproth obtained a little sulphuric acid; but this acid, as Vauquelin, with his usual ingenuity, demonstrated, was formed during the analysis.

This ore sometimes contains a minute portion of arsenic, but never more than .02[*].

GENUS IV. SALTS OF SILVER.

Sp. 1. Muriat of silver[†].

Corneous silver ore.

This ore occurs at Johanngeorgenstadt in Saxony, in South America, &c. It is often amorphous, sometimes nearly in powder, and sometimes crystallized in cubes or parallelopipeds.

Properties.

Its colours are various: when exposed to the light it becomes brown. Internal lustre greasy, 2; external 2 to 1. Acquires a gloss when scraped with a knife. Transparency 2 to 1. Texture foliated. Hardness 4 to 5. Specific gravity 4.745[‡] to 4.804[§]. Before the

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[*] Vauquelin, *Jour. de Min.* No xvii. p. 8.

[†] Kirwan, ii. 113.—Laxmann, *Nov. Comm. Petropol.* xix. 482.—Monnet, *Mem. Scav. Etrang.* ix. 717.

[‡] Brisson. [§] Gellert.

blow-pipe it instantly melts, and gradually evaporates, but may be reduced by adding an alkali.

That this ore contains muriatic acid has been long known. Mr Woulfe first shewed that it contained also sulphuric acid* ; and this discovery has been confirmed by Klaproth, according to whose analysis this ore is

Composition.

composed of . . .

67.75	silver
6.00	oxide of iron
21.00	muriatic acid
.25	sulphuric acid
1.75	alumina
96.75†	

The alumina can only be considered as mixed with the ore. Sometimes its quantity amounts to .67 of the whole‡.

ORDER IV. ORES OF MERCURY.

Situation.

MERCURY abounds in Europe, particularly in Spain, Germany, and Hungary: it is found also in China §, the Philippines ||, and in Peru, and perhaps Chili ¶ in South America. The most productive mines of mercury are those of Idria ** ; of Almaden, near Cordova in Spain, which were wrought by the Romans††; of the Palatinate ‡‡; and of Guanca Velica in Peru §§.

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* *Phil. Trans.* 1776 † Beitrage, i. 134. ‡ Ibid. p. 137.

§ See Entrecolle's *Lettres Edificantes.* || Carreri's *Voyage.*

¶ See Molina's *Natural History of Chili.*

** Scopoli, *Jour. de Min.* No. xxxiv. p. 915.

†† See Bowle's *Natural History of Spain*, and *Jour. de Min.* No. xxxi. p. 555.

‡‡ *Jour. de Min.* Nos. vi. and vii.

§§ See Ulloa's *Memoirs concerning America.*

Mercury has never been found in Britain, nor has any mine worth working been discovered in France. It occurs most commonly in argillaceous shistus, limestones, and sandstones.

Genus I.
Species I.

GENUS I. ALLOYS OF MERCURY.

Sp. 1. Native mercury.

Native mercury is found in most mercurial mines: it is in small globules, scattered through different kinds of stones, clays, and ores.

Fluid. Colour white. Specific gravity about 13.6.

Sp. 2. Amalgam of silver *.

Native amalgam.

This mineral has been found in the silver mine of Shalberg †, in the province of Dalecarlia, in Sweden; in the mines of Deux Ponts ‡, in the Palatinate; and in other places. It is in thin plates, or grains, or crystallized in cubes, parallelopipeds, or pyramids.

Its colour is silvery white or grey. Lustre metallic. Creaks when cut. Specific gravity above 10. Tinges gold white. Before the blow-pipe the mercury evaporates and leaves the silver.

Composition.

A specimen of this amalgam, analysed by Klaproth, contained

64	mercury
36	silver
100 §	

Sometimes it contains a mixture of alumina, and sometimes the proportion of mercury is so great that the amalgam is nearly as soft as paste.

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[*] Kirwan, ii. 223.

[†] Cronstedt's *Min.*

[‡] Heyer, Crell's *Annals*, 1790.

[§] Beitrage, i. 183.

Class IV.
Order IV.

GENUS II. SULPHURETS OF MERCURY.

Sp. 1. Native cinnabar [*].

This ore, which is found in almost all mercurial mines, is sometimes in veins, sometimes disseminated, sometimes in grains, and sometimes crystallized. The form of its crystals is a tetrahedron or three-ſided pyramid, most commonly wanting the summit; sometimes two of these pyramids are joined base to base; and sometimes there is a three-sided prism interposed between them [†].

Crystals.

Its colour is red. Its streak red and metallic. Lustre when crystallized 2 to 3; when amorphous, often 0. Transparency, when crystallized, from 1 to 3; when amorphous, often 0. Texture generally foliated. Hardness from 3 to 8. Specific gravity from 5.419 to 10.1285.

Before the blow-pipe evaporates with a blue flame and sulphureous smell. Insoluble in nitric acid [‡].

Varieties.

Variety 1. Dark red.—Colour cochineal red. Hardness 6 to 7. Specific gravity, when pure, 10.1285 [§]; sometimes only 7.2, or even 6.188 [||].

Variety 2. Bright red.—Colour commonly scarlet. Specific gravity 6.9022 [¶] to 5.419 [**].

Sp. 2. Hepatic mercurial ore [††].

This ore, which is the most common in the mines of Idria, is always amorphous, and is often mixed with native mercury and cinnabar.

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[*] Kirwan, ii. 228.

[†] Romé de Lisle, iii. 154.

[‡] Hauy *Jour. de Min.* No. xxxi. p. 518.

[§] Brisson.

[||] Muschenbroek.

[¶] Brisson.

[**] Gellert.

[††] Kirwan, ii. 224.

Its colour is somewhat red. Its streak dark red and brighter. Lustre commonly metallic. Hardness from 6 to 8. Specific gravity from 9.2301 * to 7.186†. When heated the mercury evaporates.

Composition.

Though this ore has never been accurately analysed, chemists have concluded that the mercury which it contains is in the state of a red oxide, because it is insoluble in nitric and soluble in muriatic acid ‡. When purest it contains about .77 of mercury §. It contains also some sulphur and iron.

Werner has divided this species into two varieties, the *compact* and the *slaty*. The second is often nothing more than bituminous shale impregnated with oxide of mercury ‖.

Genus III. Species I.

GENUS III. MERCURIAL SALTS.

Sp. 1. Muriat of mercury ¶.

Corneous mercury.

This ore, which occurs in the Palatinate, is sometimes in scales, sometimes in grains, and sometimes crystallized. Its crystals are either small four or six sided prisms; whose sides are rhombs **; or cubes; or four-sided pyramids wanting their angles. They are always very small, and generally confused.

Crystals.

Its colours are various; but it is most frequently white. Its lustre, when white, is pearly. Sometimes opaque, and sometimes semitransparent. Evaporates before the blow-pipe.

Mr Woulfe discovered that this ore generally con-

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* Brisson.

† Kirwan.

‡ Sage, *Jour. de Phys.* xxiv. 61.

§ Scopoli, *Jour. de Min.* No. xxxvi. p. 919.

‖ Kirwan, ii. 226.

¶ Ibid.

** Romé de Lisle, iii. 161.

Class IV. Order V.

tains some sulphuric acid [*]. Specimens have been found in which the quantity of sulphuric acid exceeds that of the muriatic [†].

ORDER V. ORES OF COPPER.

COPPER mines abound in most countries. They are wrought in China, Japan, Sumatra; the north of Africa; in Chili and Mexico; and in most parts of Europe; especially Britain, Germany, Russia, Sweden.

Copper is found most commonly in rocks of hornblende, shistus, and quartz.

GENUS I. ALLOYS OF COPPER.

Sp. 1. Native copper [‡].

Forms.

Native copper occurs now and then in the greater number of copper mines: Sometimes it is in masses, sometimes in plates and threads, which assume a variety of forms; and sometimes, as in Siberia, it is crystallized in cubes, or other forms nearly resembling cubes [§].

Properties.

Colour commonly that of copper, but sometimes dark brown. Lustre metallic. Streak brighter. Fracture hackly. Flexible and malleable Hardness 6 to 7. Specific gravity from 7.6 [‖] to 8.5844 [¶].

Sp. 2. White Copper ore [**].

Alloy of copper, iron, and arsenic.

This ore, which is said to be uncommon, occurs in

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[*] *Phil. Trans.* lxvi. 618.

[†] Suckow.

[‡] Kirwan, ii. 127.—Cartheuser.

[§] Hauy, *Jour. de Min.* No. xxxi. 509.

[‖] Kirwan, *Min.* ii. 128.

[¶] Hauy, *Jour. de Min.* No. xxxi. 509.

[**] Kirwan, *Min.* ii. 152.

Genus II. Species I.

masses. Colour white. Lustre metallic. Fracture uneven. Hardness 8 to 9. Brittle. Specific gravity considerable.

Before the blow-pipe gives out a white arsenical smoke, and melts into a greyish black slag *.

GENUS II. SULPHURETS OF COPPER.

Sp. 1. Common sulphuret of copper †.

Vitreous copper ore.

This ore, which is found in Cornwall, Hungary, and Siberia, occurs in masses, plates, threads, and crystallized in six-sided prisms, or four-sided pyramids, joined base to base.

Properties.

Colour bluish grey. Streak brighter grey. Lustre metallic. Hardness 4 to 7. Specific gravity 5.452 ‡ to 5.565 §; sometimes so low as 4.129 ‖. Detonates with nitre.

Before the blow-pipe it melts easily; and while in fusion exhibits a green pearl, which, on cooling, is covered with a brown crust. Tinges borax green.

Varieties.

Werner makes two varieties of this ore: the first he calls *compact*, from its texture; and the second, for the same reason, he calls *foliated*. This last is somewhat darker coloured than the first, but in other respects they agree.

Sp. 2. Copper pyrites ¶.

Yellow copper ore.

This ore, which is probably nothing else than sulphuret of iron combined with copper, and which, therefore, would be more properly placed among iron ores,

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* Widenman.

† Kirwan, ii. 144.

‡ Kirwan.

§ Gellert.

‖ Kirwan.

¶ Kirwan, ii. 140.

Class IV. Order V.

is found frequently in copper mines, and mixed with common pyrites or sulphuret of iron. It is sometimes amorphous, and sometimes crystallized. Its crystals are either three or four-sided pyramids applied base to base, or six-sided plates.

Its colour is yellow; often tarnished. Its internal lustre metallic. Hardness 6 to 7; sometimes 9. Brittle. Specific gravity 4.314* to 4.08†. Deflagrates; but does not detonate with nitre‡.

Before the blow-pipe decrepitates, gives a greenish sulphureous smoke, and melts into a black mass, which tinges borax green. Does not effervesce with nitric acid.

Sp. 3. Purple copper ore §.

This ore is found in masses, or plates, or disseminated; sometimes, also, it is crystallized in octahedrons.

Properties.

Colour various, but most commonly purple; internally reddish. Streak reddish and bright. Lustre metallic. Hardness 6 to 7. Brittle. Specific gravity 4.956 to 4.983 ||.

Effervesces with nitric acid, and tinges it green. Deflagrates with nitre. Before the blow-pipe melts readily without smoke, vapour, or smell; but is not reduced. Tinges borax a bright green.

Composition.

A specimen of this ore, analysed by Klaproth, contained . . . . 58 copper
18 iron
19 sulphur
5 oxygen

100 ¶

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* Brisson.
† Kirwan.
‡ Ibid. *Min.* ii. 141.
§ Ibid. 142.
|| Ibid. 143.
¶ Beitrage, ii. 286.

Sp. 4. Grey copper ore *.

Genus II. Species IV.

This ore is found in Cornwall, Saxony, Hungary, &c. It is often amorphous, but often also crystallized. The primitive form of its crystals is the regular tetrahedron; but, in general, either the angles or the edges, or both, are truncated or bevelled †.

Properties.

Colour steel grey; often tarnished, and then dark grey. Streak dark grey; sometimes reddish brown. Powder blackish; sometimes with a tint of red. Lustre metallic. Hardness 7 or 8. Very brittle. Specific gravity 4.8648 ‡. Deflagrates with nitre. Before the blowpipe crackles, but at last melts, especially if assisted by borax. The bead gives a white smoke, without any particular smell; tinges borax yellow, or brownish red, but does not unite with it.

Composition.

A specimen of this ore from Cremnitz, analysed by Klaproth, contained

31	copper
14	silver
34	antimony
3	iron
11	sulphur
93	

Napion, in an ore from the valley of Lanzo, found copper, silver, and antimony, nearly in the same proportions, but more iron, and some arsenic §. Savoresi, as Baron Born informs us, besides the ingredients of Klaproth's analysis, found some gold and mercury in

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* Kirwan, ii. 146. Klaproth's Beitrage, i. 177.

† Romé de Lisle, iii. 315.

‡ Hauy, *Jour. de Min.* No. xxxi. 512.

§ *Mem. Turin*, v. 173.

grey copper ore [*] : and Klaproth himself found lead in most of the other specimens which he examined.

GENUS III. OXIDES OF COPPER.

Sp. 1. Red copper ore [†].

Red copper glass.

This ore is found in Cornwall and many other countries. It occurs in masses, disseminated, in scales, and crystallized. The figure of its crystals is most commonly the regular octahedron [‡].

Properties.

Colour commonly cochineal red. Streak brick red. Lustre semimetallic. Transparency, when amorphous, generally 0; when crystallized, 3 or 4. Hardness from 4 to 7. Soluble with effervescence in nitric acid. Before the blow-pipe melts easily, and is reduced.

Composition.

This ore has been lately analysed by Mr Chenevix, who has found it when pure to consist entirely of the orange oxide of copper [§].

Werner has made three varieties of this ore, which, from their texture, he has denominated *compact*, *foliated*, and *fibrous*. The first is seldom or never found crystallized, and is opaque; the second occurs amorphous, crystallized, and in scales; the third is carmine, ruby, or scarlet red; and occurs always in short capillary crystals, or delicate flakes.

This ore sometimes contains a mixture of red oxide of iron; it is then called *brick red copper ore*, *copper malm*, *or copper ochre.*

This ore is sometimes mixed with bitumen. Its colour is then brownish black, and it is called *pitch ore.*

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[*] *Catal.* ii. 498.

[†] Kirwan, ii. 135.

[‡] Hauy, *Jour. de Min.* No. xxxi. 517.

[§] *Phil. Trans.* 1801. p. 227.

Genus IV. Species I.

Sp. 2. Green sand of Peru *.

This ore, which was brought from Peru by Dombey, is a grass green powder, mixed with grains of quartz. When thrown on burning coals, it communicates a green colour to the flame. It is soluble both in nitric and muriatic acids without effervescence. The solution is green. It was supposed to contain muriatic acid †; but Vauquelin has discovered, that the appearance of this acid was owing to the presence of some common salt accidentally mixed with the sand ‡.

GENUS IV. SALTS OF COPPER.

Sp. 1. Blue carbonat of copper §.

Mountain blue—Azur de cuivre—Blue calx of copper—Kupfer lazur.

This ore, which occurs in the copper mines of Siberia, Sweden, Germany, Hungary, Cornwall, &c. is either amorphous or crystallized. The crystals are small, and difficult to examine. According to Romé de Lisle, their primitive form is an octahedron, the sides of which are isosceles triangles, and two of them more inclined than the others ‖. Be that as it may, the crystals of blue carbonat of copper are often rhomboidal prisms, either regular, or terminated by dihedral summits ¶.

Crystals.

Its colour is azure or smalt blue. Streak blue. Hardness 4 to 6. Brittle. Specific gravity 3.608 **. It effervesces with nitric acid, and gives it a blue colour.

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* Kirwan, ii 147.

† Berthollet, *Mem. Par.* 1786, 462.

‡ *Jour. de Min.* No. xxxi. 519.

§ Kirwan, ii. 129.—Morveau, *Mem. Dijon*, 1782. 1 Semestre, p. 100.

‖ *Crystal.* iii. 343.

¶ Ibid. p. 345.

** Brisson.

Class IV. Order V.

Before the blow-pipe it blackens, but does not melt. Tinges borax green with effervescences.

The crystals, according to Pelletier, are composed of

66	to 70	copper
18	— 20	carbonic acid
8	— 10	oxygen
2	— 2	water

Fontana first discovered that this ore contained carbonic acid gas. The copper is evidently in the state of hydrat.

Varieties.

Variety 1. Mountain blue.—This variety generally contains a mixture of lime. It is never crystallized; and sometimes is almost in the state of powder. Lustre 0. Texture earthy.

Variety 2. Striated blue carbonat of copper.—Lustre glassy. Transparency, when crystallized, 2; when amorphous, 1. Texture striated; sometimes approaching to the foliated.

Sp. 2. Green carbonat of copper *.

Malachite.

This ore is generally amorphous, but sometimes it is crystallized in four-sided prisms, terminated by four-sided pyramids.

Properties.

Colour green. Lustre silky. Hardness 5 to 7. Brittle. Specific gravity 3.571 † to 3.653 ‡. Effervesces with nitric acid, and gives a blue colour to ammonia. Before the blow-pipe it decrepitates and blackens, but does not melt. Tinges borax yellowish green.

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[*] Kirwan, ii. 131.—Fontana, *Jour. de Phys.* xi. 509.—Klaproth's Beitrage, ii. 287.

[†] Brisson.

[‡] Kirwan.

Genus IV. Species III.

It is composed of carbonic acid and green oxide of iron.

Variety 1. Fibrous malachite.—Texture fibrous. Opaque when amorphous; when crystallized its transparency is 2. Colour generally grass green.

Variety 2. Compact malachite.—Texture compact. Opaque. Colour varies from the dark emerald green to blackish green.

Composition.

A specimen of malachite from Siberia, analysed by Klaproth, contained

58.0	copper
18.0	carbonic acid
12.5	oxygen,
11.5	water
100*	

This species is sometimes mixed with clay, chalk, and gypsum, in various proportions; it is then known by the name of

Common mountain green.

Its colour is verdigris green. Lustre 0. Transparency 0 to 1. Hardness 3 to 4. Brittle. Texture earthy. Effervesces feebly with acids. Before the blowpipe it exhibits the same phenomena as malachite.

Sp. 3. Sulphat of copper.

This salt is found sometimes dissolved in water. It belongs properly to mineral waters. Its properties have been already detailed in the First Part of this Work.

Sp. 4. Arseniat of copper.

This mineral was discovered above 20 years ago in the Carrarach mine in the county of Cornwall; but it

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* Beitrage, ii. 290.

Class IV. Order V.

had become exceedingly scarce till it was lately found in abundance in the Huel Garland mine. A great variety of specimens were carried to London; and they have been admirably described and analysed by the Count de Bournon and Mr Chenevix [*].

This mineral is most commonly crystallized. Its colour is usually blue or green; sometimes brown; and when decomposing almost black. Generally transparent unless when decomposing. Hardness from 4 to 8. Specific gravity from 2.548 to 4.280. There are four varieties, distinguished from each other by the proportion of their component parts.

Varieties.

Variety 1. *Octahedral* arseniat.—Crystallized in obtuse octahedrons, composed of two four-sided pyramids with isosceles triangular faces, two of which are more inclined than the other two. The two most inclined meet at the apex at an angle of 130°, and form at the base angles of 50°: the two least inclined meet at the apex in an angle of 115°, and form at the base angles of 65°. Sometimes the apex is converted into a ridge; the octahedron being lengthened parallel to the less inclined planes. Colour deep sky blue; sometimes grass green, sometimes bluish white. Specific gravity 2.881. Transparency 2 to 3. Hardness 6.

Variety 2. *Hexahedral* arseniat.—Crystallized in thin hexahedral laminæ; the six faces inclined alternately towards the opposite sides of the plates, so that three lie one way and three another. Two of these three are inclined at angles of 135°; the other at an angle of 115°. Colour deep emerald green. Divisible into thin plates like mica. Specific gravity 2.548. Hardness

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[*] *Phil. Trans.* 1801, p. 169.

Genus IV. Species IV.

5. Transparency of thin plates 4. Decrepitates when heated.

Variety 3. *Acute octahedral* arseniat.—Crystallized in acute octahedrons, composed like the first variety of pyramids, having two faces more inclined than the other two The more inclined faces meet at the apex in an angle of 84°, and form at the base angles of 96°. The less inclined form at the apex an angle of 68° at the base of 112°. The apex often converted into a ridge. Sometimes crystallized in four-sided rhomboidal prisms, with angles of 84° and 96°, and terminated by dihedral summits. Edges which correspond to the angles of 96° often truncated. Sometimes the crystals are capillary, and even terminate in a bundle of fine fibres; sometimes composed of fibres like amianthus, and sometimes in thin layers of a fibrous texture. Colour usually brown or bottle green, so dark as to appear blackish. Transparency 3 to 4. Specific gravity 4.280. Hardness 8.

Variety 4. *Trihedral* arseniat.—Crystallized in trihedral prisms; the bases of which are equilateral triangles, very small, and subject to a great number of variations; for a description of which the reader is referred to the Count de Bournon *. Specific gravity 4.280. Hardness 7. Colour bluish green; when decomposing blackish.

The analysis of these different varieties has been already detailed in a former part of this Work †.

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* *Phil. Trans.* 1801, p. 182.

† See Vol. II. p. 506.

Class IV.
Order VI.

ORDER VI. ORES OF IRON.

IRON is the most abundant of metals; it exists almost everywhere, and assumes the most different and even opposite shapes. This renders it a more difficult task to bring its ores under a regular arrangement than those of any other metal. They may, however, be all arranged under six different genera.

GENUS I. ALLOYS OF IRON.

Sp. 1. Native iron [*].

Native iron has been found in Siberia and in Peru in immense masses, which seemed as if they had been fused. These masses evidently did not originate in the place where they were found.

Colour bluish white. Fracture hackly. Lustre metallic. Malleable. Magnetic. Hardness 8 to 9. Specific gravity 7.8. Proust has discovered, that the native iron found in Peru is alloyed with nickel [†].

GENUS II. SULPHURETS.

Sp. 1. Sulphurated oxide of iron [‡].

Pyrites.

This mineral occurs very frequently both in ores and mixed with other bodies, for instance in slates. It is often amorphous, and often also crystallized. The primitive form of its crystals is either a regular cube or an

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[*] Pallas, *Phil. Trans.* lxvi. 523.—Rubin de Celis, Ibid. lxxviii. 37.—See also Schreiber, *Jour. de Phys.* xli. 3.; and Stelin, *Phil. Trans.* lxiv. 461.

[†] Nicholson's *Journal*, iii. 374.

[‡] Kirwan, ii. 76.—Henkel's *Pyritologia.*

Genus II. Species I.

octahedron. The varieties of its form hitherto described amount to 30; for a description of which I refer the reader to Romé de Lisle*.

Properties. Its colour is yellow. Its lustre metallic. Hardness 8 to 10. Brittle. Specific gravity 3.44 to 4.6. Soluble in nitric acid with effervescence. Scarce soluble in sulphuric acid. Before the blow-pipe burns with a blue flame and a sulphureous smell, and leaves a brownish bead, which tinges borax of a smutty green.

Varieties. *Variety* 1. Common pyrites.—Fracture uneven. Hardness 10. Decrepitates when heated. Emits a sulphureous smell when rubbed. Not magnetic. It occurs often in coal mines and in slates.

Variety 2. Striated pyrites.—Texture striated. Hardness 10. Not magnetic.

Variety 3. Capillary—Colour often steel grey. Found in needleform crystals. Uncommon. Not magnetic.

Variety 4. Magnetic pyrites.—Found in masses. Texture compact. Hardness 8 to 9. Slightly magnetic. Seems to contain less sulphur than the other varieties.

Pyrites is composed of sulphur and the black oxide of iron. The proportion of sulphur is variable, which explains the varieties of its crystalline forms.

GENUS III. CARBURET OF IRON

Sp. 1. Plumbago†.

Graphite of Werner.

This mineral is found in Britain, Germany, France, Spain, America, &c. It occurs in kidney-form lumps of various sizes. Its colour is dark iron grey or brownish black; when cut, bluish grey. Lustre metallic,

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[*] *Crystal.* iii. 208.

[†] Kirwan, ii. 58.

Class IV. Order VI.

from 3 to 4. Opaque. Structure slaty. Texture fine grained. Hardness 4 to 5. Brittle. Specific gravity from 1.987 to 2.089; after being soaked in water, 2.15; after being heated, 2.3; and when heated after that, 2.41 *. Feels somewhat greasy. Stains the fingers, and marks strongly. The use of this mineral when manufactured into pencils is known to every person.

Composition.

Its composition was discovered by Scheele. When pure it contains

90	carbon
10	iron
100	

But it is often exceedingly impure: A specimen, for instance, from the mine of Pluffier, in France, analysed by Vauquelin, contained

23	carbon
2	iron
38	silica
37	alumina
100 †	

Genus IV. Iron combined with Silica.

Sp. 1. Emery ‡.

This mineral is commonly disseminated through other fossils, but sometimes in the East Indies it occurs in large masses.

Properties.

Its colour is bluish grey, greyish brown, or bluish black, often covered with a yellowish rind; internally it discovers red or purple spots. Lustre 1 or 0; in some parts 2, and metallic. Opaque. Hardness 14. Brittle. Specific gravity 3.92 §. Before the blow-pipe

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* Brisson.

† *Jour. de Min.* No. xii. p. 16.

‡ Kirwan, ii. 193.

§ Brisson.

Genus V.
Species I.

it blackens and gives a smutty yellow tinge to borax.

According to Wiegleb it contains

95.6	silica
4.3	iron
99.9	

Genus V. Oxides of Iron.

This genus is very extensive; for iron is much more frequently found in the state of an oxide than in any other.

The minerals belonging to it may be all arranged under two species; because they all contain iron, either in the state of black oxide or of red. But it will be necessary to branch out each of these species into several *subspecies*, and these again into *varieties*.

Sp. 1. Black oxide.

The minerals belonging to this species are all somewhat affected by the magnet, and they have usually the metallic lustre and appearance. They may be arranged under five subspecies.

Subspecies 1. Octahedral iron ore.

Common magnetic ironstone.

This ore is very common in Sweden; it is found also in Switzerland, Norway, Russia, &c. It occurs in masses, plates, grains, and crystallized. The primitive form of its crystals is a regular octahedron[*]. Sometimes two opposite sides of the pyramids are trapeziums, which renders the apex of the pyramids cuneiform. Sometimes the crystals pass into rhomboidal

Crystals.

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[*] Romé de Lisle, iii. 178.

parallelopipeds, and into dodecahedrons with rhomboidal faces[*].

Properties.

Its surface is brownish black; internally bluish grey. Powder black[†]. Streak blackish grey, brighter. Lustre metallic. Hardness 9 to 10. Brittle. Specific gravity from 4.094 to 4.688[‡]. Attracted by the magnet, and generally possessed of more or less magnetic virtue[§]. To this subspecies belongs the magnet. Before the blow-pipe it becomes browner, but does not melt. Tinges borax dark green.

When pure it consists entirely of black oxide of iron; but it is often mixed and contaminated with foreign ingredients.

Subspecies 2. Magnetic sand[¶].

This substance is found in Italy, Virginia, St Domingo, the East Indies, and in the sand of the river Don at Aberdeen in Scotland. It is black, very hard, magnetic. Specific gravity about 4.6. Not altered by the blow-pipe *per se;* melts into a black glass with potass, and into a green glass with microcosmic salt, both opaque[**]. It probably contains some silica, as Kirwan has supposed[††].

Subspecies 3. Specular iron ore[††].—*Fer oligiste.*

This ore is found abundantly in the isle of Elba near Tuscany. It is either in masses or crystallized. The

Crystals.

primitive form of its crystals, and of its integrant molecules, is the cube[§§]. The varieties hitherto observed

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[*] Romé de Lisle, iii. 178.

[†] Hauy, *Jour. de Min.* No. xxxiii. 659.

[‡] Kirwan's *Min.* ii. 159.

[§] Hauy, *Jour. de Min.* No. xxxi. 527.

[¶] Kirwan, ii.—Dupuget, *Jour. de Min.* No. xxi. p. 75.

[**] Fourcroy, *Ann. de Chim.* ii. 127.

[††] *Min.* ii. 161.

[‡‡] Kirwan, ii. 162.—Coudrai, *Jour. de Phys.* iv. 52.

[§§] Hauy, *Jour. de Min.* No. xxxiii. 660.

amount to 7. These are the rhomboidal parallelopiped; the cube, with three triangular faces instead of two of its angles diagonally opposite; two six-sided pyramids, applied base to base, wanting the summits, and sometimes the angles at the bases, and sometimes the alternate edges of the pyramid; a polyhedron of 24 sides, resembling a cube with three triangular faces for two angles diagonally opposite, and two triangles for the rest of its angles. For a description and figure of these varieties, I refer to Romé de Lisle* and Hauy†.

Properties.

Colour steel grey; often tarnished, and beautifully iridescent, reflecting yellow, blue, red. Streak red. Powder dark red. Lustre metallic. Hardness 9 to 10. Not brittle. Specific gravity 5.0116‡ to 5.218§. Slightly magnetic. Little altered by the blow-pipe. Tinges borax an obscure yellow.

Composition.

This ore, according to Mr Mushet, is composed of

66.1	iron
21.2	oxygen
10.7	water and carbonic acid
2.0	lime
100.0‖	

The quantity of oxygen here stated is probably too small, owing to the unavoidable inaccuracy which results from the *dry way* of analysis which Mr Mushet followed.

Subspecies 4. Micaceous iron ore.

This ore is generally considered as a variety of the

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* *Crystall.* iii. 189. † Ibid. 660. ‡ Hauy. § Brisson.

‖ *Phil. Mag.* iii. 354.

Class IV.
Order VI.

last. Kirwan, however, supposes it to contain carbon, and to be a distinct species.

It is found in Saxony, and in the isle of Elba, &c. generally in amorphous masses, composed of thin six-sided laminæ. Colour iron grey. Streak bluish grey. Lustre metallic. Opaque. Feel greasy. Hardness 5 to 7. Brittle. Specific gravity from 4.5 to 5.07. Slightly magnetic. Infusible by the blow-pipe. Tinges borax greenish brown.

Subspecies 5. Laminated specular iron ore.

Fer pyrocete of Hauy.

This ore, which is found at Montd'or in Auvergn, was usually arranged under the last species; but has been separated from it by Mr Hauy, because the form of its crystals is incompatible with the supposition that their primitive nucleus is a cube, as we have seen is the case with common specular iron ore. Its crystals are thin octagonal plates, bounded by six linear trapeziums, alternately inclined different ways*.

Colour steel grey. Powder reddish black. Lustre metallic; surface polished. Fracture glassy. Very brittle†. Hauy supposes that this ore has been produced by fire, and accordingly has given it a name which denotes its origin.

Sp. 2. Red oxide.

The minerals belonging to this species are not affected by the magnet; and it is but rarely that they possess the metallic lustre. In all of them the red oxide is combined with some substance or other; and alumina, or rather clay, is the most common ingredient. The oxide of manganese, too, seems to be frequently present.

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* Romé de Lisle, iii. 188.

† Hauy, *Jour. de Min.* No xxxi. 33.

These minerals are very numerous, but they may be arranged under four subspecies.

Genus V. Species II.

Subspecies 1. Brown iron ore*.

This species of ore is found abundantly in Britain, particularly in Cumberland and Lancashire; and it is also very common in other counties. It consists of the brown oxide of iron, more or less contaminated with other ingredients.

Properties.

Its colour is brown. Its streak reddish brown. Specific gravity from 3.4771 to 3.951. Before the blowpipe blackens, but does not melt. Tinges borax greenish yellow.

Varieties.

Variety 1. Brown hæmatites.—The name hæmatites (bloodstone) was probably applied by the ancients to those ores only which are of a red colour, and have some resemblance to clotted blood; but by the moderns it is applied to all the ores of iron which give a reddish coloured powder, provided they be of a fibrous texture.

Brown hæmatites occurs in masses of various shapes, and it is said also to have been found crystrallized in five or six-sided acute angled pyramids. Colour of the surface brown or black, sometimes iridescent; internally nut brown. Powder red. Texture fibrous. Hardness 8 to 10. Brittle. Specific gravity 3.789 † to 3.951 ‡. Not magnetic.

This variety has not been analysed, but it seems to consist of red oxide of iron, oxide of manganese, and alumina §.

Variety 2. Compact brown iron stone.—This variety occurs in masses of very various and often fantastical

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* Kirwan, ii. 163.

† Gellert.

‡ Kirwan.

§ Kirwan's *Min.* ii. 164.

Class IV. Order VI.

shapes. Colour brown. Internal lustre metallic. Texture compact. Hardness 6 to 9. Brittle. Specific gravity 3.4771 * to 3.551 †.

Variety 3. Brown scaly iron ore.—This variety is generally incumbent on other minerals. Colour brown. Lustre metallic. Stains the fingers, marks strongly. Feels unctuous. Texture foliated. Hardnes 3 to 5. Brittle. So light as often to float on water.

Variety 4. Brown iron ochre.—This variety occurs both massive and disseminated. Colour from nut brown to orange. Lustre 0. Strongly stains the fingers. Texture earthy. Hardness 3 to 4. When slightly heated reddens.

Subspecies 2. Red iron ore ‡.

Colour red. Streak blood red. Specific gravity from 3.423 to 5.005. Before the blow-pipe blackens, but does not melt. Tinges borax yellowish olive green. When digested in ammonia, it becomes black and often magnetic.

Varieties.

Variety 1. Red hæmatites.—Found in masses, and all the variety of forms of stalactites. Colour between brownish red and steel grey. Powder red. Internal lustre metallic. Texture fibrous. Hardness 9 to 10. Brittle. Specific gravity 4.74 § to 5.005 ¶. When pure it consists of red oxide of iron, but it often contains manganese and alumina **.

Variety 2. Compact red iron ore.—Found massive and stalactitic; sometimes in crystals of various forms, but they seem to be only secondary; sometimes in columns like basalt. Colour between brown red and steel

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* Brisson.
† Kirwan.
‡ Ibid. ii. 168.
§ Gillert.
¶ Kirwan.
** Ibid. ii. 169.

grey. Stains the fingers. Lustre 1 to 0; often semimetallic. Texture compact. Hardness 7 to 9. Brittle. Specific gravity 3.423 to 3.76 *. Sometimes invested with a rosy red ochre.

Variety 3. Red ochre.—Found sometimes in powder, sometimes indurated. Colour blood red. Stains the fingers. Lustre 0. Texture earthy. Hardness 3 to 5. Brittle.

Variety 4. Red scaly iron ore.—This variety is generally found incumbent upon other iron ores. Colour between cherry red and steel grey. Stains the fingers. Lustre silky, inclining to metallic. Texture foliated. Feels unctuous. Hardness 3 to 4. Brittle. Heavy.

Subspecies. 3. Argillaceous iron ore †.

Oxide of iron combined or mixed with clay.

This ore is exceedingly common; and though it contains less iron than the species already described, it is, in this country at least, preferred to them, because the method of extracting pure iron from it is easier, or rather because it is better understood.

Properties.

Colour most commonly dark brown. Streak red or yellowish brown. Specific gravity from 2.673 to 3.471 ‡. Before the blow-pipe blackens, and tinges borax olive green and blackish. It is composed of oxide of iron, alumina, lime, silica in various proportions. It generally yields from 30 to 40 *per cent.* of iron.

Varieties.

Variety 1. Common argillaceous iron ore.—The minerals arranged under this variety differ considerably from each other in their external characters. They are found in masses of various shapes, and often form large strata. Colour various shades of grey, brown,

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* Kirwan.

† Ibid. ii. 173.

‡ Kirwan.

yellow, and red. Streak reddish yellow or dark red. Lustre 0. Hardness from 3 to 8. Smell earthy when breathed upon.

Variety 2. Columnar or scapiform iron ore.—This variety is found in columns adhering to each other, but easily separable: They are commonly incurvated, and their surface is rough. Colour brownish red. Streak dark red. Slightly stains the fingers. Lustre 0. Adheres strongly to the tongue. Sound hollow. Feel dry. Texture earthy.

Variety 3. Acinose iron ore.—This variety is found in masses, and is commonly lenticular. Colour generally brownish red. Lustre metallic, nearly. Texture granular. Hardness 5 to 9. Brittle.

Variety 4. Nodular, or kidney-form ore. *Ætites* or *Eaglestone*.—This variety, which was mentioned by the ancients, is generally found under the form of a rounded knob, more or less resembling a kidney, though sometimes it is quadrangular; and it contains within it a kernel, which is sometimes loose, and sometimes adheres to the outside rind. Colour of the stone yellowish brown; of the kernel ochre yellow. Surface generally fouled with earth. Lustre of the rind metallic; of the kernel 0. Hardness from 4 to 7. Brittle.

Variety 5. Pisiform or granular iron ore.—This variety occurs in rounded masses, from the size of a pea to that of a nut. Surface rough. Colour commonly dark brown. Streak yellowish brown. Hardness 5 to 6. Brittle. The oolitic ore found at Creusot, near mount Cenis, belongs to this variety. It is composed

of	50 lime
	30 iron
	20 alumina
	100

Subspecies 4. Lowland iron ore *.

Composition.

This species of ore is supposed to consist of oxide of iron, mixed with clay and phosphuret or phosphat of iron. It is called lowland ore, because it is found only in low grounds; whereas the last species is more commonly in high grounds; and is therefore called *highland ore.* This ore occurs in amorphous masses, and also in grains or powder. Its colour is brown. Streak yellowish brown. Lustre 0, or common. Texture earthy. Hardness 3 to 5.

Varieties.

Variety 1. Meadow lowland ore.—Colour blackish or yellowish brown: Both colours often meet in the same specimen. Found in lumps of various sizes, often perforated. Fracture compact. Moderately heavy. Frequently yields from 32 to 38 *per cent.* of iron.

Variety 2. Swampy iron ore.—This variety is generally found under water. It is in lumps, which are commonly perforated or corroded, and mixed with sand. Colour dark yellowish brown, or dark nut brown. Hardness 3 to 4. Brittle. Specific gravity 2.944. It often contains .36 of iron.

Variety 3. Morassy iron ore.—This variety is found either in a loose form or in perforated lumps. Colour light yellowish brown. Stains the fingers. Hardness 3. Friable.

GENUS VI. SALTS OF IRON.

Sp. 1. Sparry iron ore †.

This ore is common in Germany, France, and Spain.

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[*] Kirwan, ii. 179.

[†] Kirwan, ii. 190.—Bergman, ii. 184.—Bayen, *Jour. de Phys.* vii. 213. Razowmowski, *Mem. Lausanne*, 1783, p. 149.

Class IV.
Order VI.

It is found sometimes in amorphous masses, and sometimes crystallized.

Properties.

Its colour is white; but it becomes tarnished by exposure to the air, and then assumes various colours. Streak grey or white. External lustre often metallic; internal common or glassy. Transparency 1 or 2; sometimes 0. Texture foliated. Fragments rhomboidal. Hardness 5 to 7. Brittle. Specific gravity 3.6 to 3.810. Not magnetic. Soluble in acids with very little effervescence. Before the blow-pipe decrepitates, becomes brownish black, and magnetic; but is scarcely fusible. Tinges borax smutty yellow, with some effervescence.

This ore, as Bergman ascertained, consists of iron, manganese, lime, and carbonic acid.

Composition.

One specimen, according to his analysis, contained

38	iron
24	manganese
38	carbonat of lime
100	

Another contained

22	iron
28	manganese
50	carbonat of lime
100	

Whether the iron be combined with the carbonic acid is still a disputed point. The crystals of this ore are rhomboidal parallelopipeds; which is precisely the form of carbonat of lime. This amounts nearly to a demonstration, that the carbonic acid is combined with the lime; and that, as Cronstedt and Hauy have supposed, this ore is merely carbonat of lime, contaminated with a quantity of the oxides of iron and manganese.

Sp. 2. Arseniat of iron.

Genus VI. Species II.

This ore was first mentioned by Klaproth, but mistaken by him for arseniat of copper containing iron *: it has been found also in Muttrell mine in Cornwall. For the description of it we are indebted to Bournon, and for its analysis to Chenevix.

Crystals.

This ore is crystallized in cubes, which are sometimes a little flattened, and in some cases the angles are truncated, and small equilateral triangular faces substituted for them. Sometimes the alternate angles only are truncated. Colour dark green with a brownish tinge; sometimes brownish yellow. Transparency about 3. Hardness 7. Specific gravity 3.000. Sometimes in the state of a powder of a reddish yellow colour †. According to the analysis of Chenevix, it is composed of

Composition.

45.5	oxide of iron
31.0	arsenic acid
9.0	oxide of copper
4.0	silica
10.5	water and loss
100.0 ‡	

Sp. 3. Arseniat of iron-and-copper.

This ore has been found in Carrarach and Muttrell mines in Cornwall. It was discovered likewise in Spain by Proust §, and in Siberia by Pallas ||. It was first mentioned by Klaproth, who considered it as an arseniat of copper ¶; but the experiments of Mr Che-

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* Klaproth's *Observations on the Minerals of Cornwall*, p. 29. English Translation.

† *Phil. Trans.* 1801, p. 190.

‡ Ibid, p. 221.

§ *Ann. de Chim.* i. 195.

|| *Phil. Trans.* 1801, p. 219.

¶ Klaproth's *Observations on the Minerals of Cornwall*, p. 29. English Translation.

Class IV. Order VII.

nevix have proved it to be a triple salt, composed of the arsenic acid, combined with the oxides of iron and copper.

Crystals.

This ore crystallizes in a four-sided rhomboidal prism, having two of its edges very obtuse, and two very acute. The prism is terminated by a pretty acute four-sided pyramid. Very often the obtuse edges, and sometimes all the edges of the prism, are truncated. Colour bluish white. Transparency of the crystals 4. Hardness 7. Specific gravity 3.400 *. According to the analysis of Chevenix, it is composed of

Composition.

33.5	arsenic acid
27.5	oxide of iron
22.5	oxide of copper
12.0	water
3.0	silica
98.5 †	

Sp. 4. Sulphat of iron.

This salt is found sometimes dissolved in water. It belongs more properly to mineral waters. Its properties have been described in a former part of this Work.

Sp. 5. Tungstat of iron. See Order XVII. Genus II.

ORDER VII. ORES OF TIN ‡.

TIN ores are by no means so common as the ores of the metals which have been already described. They are found only in the *primitive mountains*. Hence Werner supposes them to be the most ancient of all metallic

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* Bournon, *Phil. Trans.* 1801, p. 191.

† Ibid, p. 220.

‡ Geoffroy, *Mem. Par.* 1738, p. 103.—Morveau, *Ann. de Chim.* xxiv. 127.

ores. They occur most frequently in granite, sometimes in porphyry, but never in limestone.

Genus I. Species I.

Almost the only tin mines known to Europeans are those of Cornwall, Devonshire, Saxony, Bohemia, Silesia, Hungary, Gallicia; those of the island of Banca and the peninsula of Malacca in India; and those of Chili and Mexico in America.

GENUS I. SULPHURETS OF TIN.

Sp. 1. Sulphuret of tin and copper*.

Tin pyrites.

Hitherto this ore has only been found in Cornwall. There is a vein of it in that country, in the parish of St Agnes, nine feet wide, and twenty yards beneath the surface †.

Properties.

Its colour is yellowish grey, passing into the steel grey. Not unlike grey copper ore. Lustre metallic. Hardness 5 to 6. Very brittle. Specific gravity 4.35 ‡. Before the blow-pipe it melts easily, with a sulphureous smell, into a black bead, and deposits a bluish oxide on the charcoal.

Composition.

The composition of this ore, as Klaproth informs us, was first discovered by Mr Raspe. According to Klaproth's analysis, it is composed of

34	tin
36	copper
25	sulphur
3	iron
2	earth
100 §	

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* Kirwan, ii. 200.

† Klaproth's *Cornwall*, p. 21.

‡ Klaproth.

§ Id. 58.

GENUS II. OXIDES OF TIN.

Sp. 1. Brown oxide of tin*.

Tinstone—Woodtin.

This ore, which may be considered as almost the only ore of tin, occurs in masses, in rounded pieces, and crystallized. These crystals are very irregular. Hauy supposes that their primitive form is a cube†; but Romé de Lisle, with more probability, makes it an octahedron‡; and in this opinion Mr Day agrees with him §. The octahedron is composed of two four-sided pyramids, applied base to base. The sides of the pyramids are isosceles triangles, the angle at the vertex of which is 70°, and each of the other angles 55°. The sides of the two pyramids are inclined to each other at an angle of 90° ||. This primitive form, however, never occurs, but crystals of tinstone are sometimes found in which the two pyramids are separated by a prism. For a complete description of the varieties of the crystals of tinstone, the reader may consult Romé de Lisle and Mr Day¶.

Crystals.

Its colour is commonly brown. Streak grey. Hardness 9 to 10. Specific gravity 6.9 to 7.0. Brittle.

Varieties.

Variety 1. Common tinstone.—Colour dark brown; sometimes yellowish grey, and sometimes nearly white Streak light grey. Somewhat transparent when crystallized. Hardness 10. Specific gravity 6.9 to 6.97. Before the blow-pipe it decrepitates, and on charcoal is partly reduced. Tinges borax white.

According to Klaproth, it is composed of

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[*] Kirwan, ii. 197.

[†] *Jour. de Min.* xxxii. 576.

[‡] *Crystallog.* iii. 413.

[§] *Phil. Mag.* iv. 152.

[||] Romé de Lisle, Ibid.

[¶] Ibid.

77.50	tin
21.50	oxygen
.25	iron
.75	silica
100.00*	

Variety 2. Woodtin.—This variety has hitherto been found only in Cornwall. It occurs always in fragments, which are generally rounded. Colour brown; sometimes inclining to yellow. Streak yellowish grey. Opaque. Texture fibrous. Hardness 9. Specific gravity 7.0. Before the blow-pipe becomes brownish red; decrepitates when red hot, but is not reduced.

Klaproth obtained from it .63 of tin; and in all probability it is an oxide of tin nearly pure.

ORDER VIII. ORES OF LEAD.

ORES of lead occur in great abundance in almost every part of the world. They are generally in veins; sometimes in siliceous rocks, sometimes in calcareous rocks.

GENUS I. SULPHURETS OF LEAD.

Sp. 1. Galena, or pure sulphuret of lead [†].

This ore, which is very common, is found both in masses and crystallized. The primitive form of its crystals is a cube. The most common varieties are the cube, sometimes with its angles wanting, and the octahedron, composed of two four-sided pyramids applied base to base. The summits of these pyramids are some-

Crystals.

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[*] Beitrage, ii. 256.

[†] Kirwan, ii. 216.

times cuneiform, and sometimes their solid angles are wanting[*].

Properties. Its colour is commonly bluish grey like lead. Streak bluish grey and metallic. Lustre metallic. Sometimes stains the fingers. Texture foliated. Fragments cubical. Hardness 5 to 7; sometimes even 9. Brittle. Specific gravity 6.884 to 7.786[†]. Effervesces with nitric and muriatic acids. Before the blow-pipe decrepitates, and melts with a sulphureous smell; part sinks into the charcoal.

It is composed of from .45 to .83 lead, and from .086 to .16 of sulphur. It generally contains some silver, and sometimes also antimony and zinc.

Varieties. *Variety* 1. Common galena.—This variety corresponds nearly with the above description. Specific gravity 7.051 to 7.786. Sometimes stains the fingers.

Variety 2. Compact galena.—Found only in amorphous masses. Texture compact, inclining to foliated. Hardness 6 to 8. Specific gravity 6.886 to 7.444. Lustre common. Streak lead grey, brighter, and metallic. Often feels greasy, and stains the fingers.

Sp. 2. Black lead ore[‡].

This ore, which is found in Germany and Brittany, and which is supposed to be common galena decayed, is sometimes in stalactites of various forms, and sometimes crystallized in six-sided prisms, which are generally truncated and confused.

Properties. Colour black, often with some streaks of red. Streak light bluish grey. Internal lustre metallic. Hardness 5 to 6. Brittle. Specific gravity from 5.744[§] to 5.77[¶].

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[*] Romé de Lisle, iii. 364.

[†] Watson.

[‡] Kirwan, ii. 221.

[§] Brisson.

[¶] Gellert.

Before the blow-pipe decrepitates, melts easily, and is reduced.

According to the experiments of Laumont, this ore is a sulphuret of lead (or rather sulphurated oxide of lead), mixed with some phosphat of lead.

Sp. 3. Blue lead ore*.

This ore, which is found in Siberia, Germany, and Hungary, and is very rare, occurs sometimes in masses, and sometimes crystallized in six-sided prisms.

Colour between indigo blue and lead grey; sometimes inclining to black. Internal lustre metallic. Streak brighter. Texture compact. Hardness 6. Specific gravity 5.461 †. Before the blow-pipe melts with a low blue flame and a sulphureous smell, and is easily reduced.

Sp. 4. Sulphuret of lead with silver and antimony ‡.

Plumbiferous antimoniated silver ore.

Found in amorphous masses. Colour grey. Hardness 5 to 6. Brittle. Specific gravity from 5.2 to 8.

Varieties.

Variety 1. Light grey silver ore.—Colour light bluish grey. Streak light bluish grey, and brighter. Lustre metallic. Texture compact. Before the blow-pipe partly evaporates, and leaves a silver bead on the charcoal surrounded by yellow dust. According to Klaproth, it contains

48.06	lead
20.40	silver
7.88	antimony
12.35	sulphur
2.25	iron
7.00	alumina
.25	silica
98.09 §	

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* Kirw. ii. 220.

† Gellert.

‡ Kirw. ii. 129.

§ Beitrage, i. 172.

Class IV.
Order VIII.

Variety 2. Dark grey silver ore.—Colour iron grey, verging on black. Powder black, and stains the fingers. Lustre 0. Texture earthy.

According to Klaproth, it contains

41.00	lead
21.50	antimony
29.25	silver
22.00	sulphur
1.75	iron
1.00	alumina
.75	silica
97.25 [*]	

Sp. 5. Bismuthic silver ore [†].

Sulphuret of lead, bismuth, and silver.

This ore, which occurs in the valley of Schapbach in Saxony, was first taken notice of by Selb, and afterwards described by Weidenmann and Emerling.

Its colour is light bluish grey. Its lustre metallic. Its fracture uneven. Hardness 5. Melts easily before the blow-pipe, emitting some smoke, and leaves a silver bead.

Composition.

A specimen, analysed by Mr Klaproth, contained

33.0	lead
27.0	bismuth
15.0	silver
16.3	sulphur
4.3	iron
0.9	copper
96.5 [‡]	

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[*] Beitrage, i. 175.

[†] Kirwan, ii. 128.

[‡] Beitrage, ii. 297.

GENUS II. OXIDES OF LEAD.

Genus II. Species I.

Sp. 1. Lead ochre *.

This ore, which is a mixture of the oxide of lead with various earths, is found massive, and of various degrees of hardness.

Properties.

Its colour is either yellow, grey, or red. Lustre 0. Transparency 0 to 1. Hardness 6 to 8; sometimes in powder. Specific gravity from 4.165 to 5.545 †. Texture compact. Effervesces with nitric and muriatic acids. Easily reduced by the blow-pipe, leaving a black slag, unless the lead be mixed with too great a proportion of earth.

GENUS III. SALTS OF LEAD.

Sp. 1. Carbonat of lead ‡.

White lead spar.

This ore of lead, which is very common, is sometimes in masses, and sometimes crystallized. But the crystallization is in general so confused, that the primitive form of the crystals has not yet been ascertained §.

Properties.

Its colour is white. External lustre, waxy or silky, from 3 to 1; internal 1 to 2. Generally somewhat transparent. Hardness 5 to 6. Brittle. Specific gravity 7.2357 ||. Effervesces with nitric and muriatic acids when they are heated. Soluble in fat oils. Blackened by sulphuret of ammonia **. Decrepitates when heated. Before the blow-pipe, in a silver spoon, it becomes red by the yellow cone of the flame, while the blue cone renders it yellow ††. On charcoal it is immediately reduced.

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* Kirwan, ii. 205. † Kirwan. ‡ Kirwan, ii. 203.

§ See Hauy, *Jour. de Min.* No. xxxi. 502. and Romé de Lisle, iii. 380.

|| Bournon, Nicholson's *Jour.* iv. 220. ** Pelletier, *Ann. de Chim.* ix. 56.

†† Ribbentrop, *Ann. de Chim.* xxv. 189.

Class IV. Order VIII.

It contains from .60 to .85 of lead, and from .18 to .24 of carbonic acid. It is generally contaminated with carbonat of lime and oxide of iron.

Sp. 2. Murio-carbonat of lead.

Crystals.

For the first description of this ore, which has hitherto been observed in Derbyshire and the Hartz only, we are indebted to the Count de Bournon. The primitive form of its crystals is the cube, often lengthened, and the edges or the angles not unfrequently truncated, and replaced by small planes. Colour usually a light straw yellow; sometimes a clear transparent white, with a lustre far surpassing common carbonat of lead. Fracture glassy, and resembling that of precious stones. Scratched by carbonat of lead. Specific gravity 6.0651*.

Composition.

According to the analysis of Mr Chevenix, it is composed of . . . . . 85 oxide of lead
8 muriatic acid
6 carbonic acid
—
99;

or, which is the same thing, of 59 muriat of lead
40 carbonat of lead
—
99†

Sp. 3. Phosphat of lead‡.

Crystals.

This ore, which is found in Siberia, Scotland, England, Germany, Carinthia, Brittany, &c. is sometimes amorphous, and sometimes crystallized. The primitive form of its crystals, according to Romé de Lisle, is a dodecahedron, consisting of a six-sided rectangular prism, terminated by six-sided pyramids, the sides of

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* Bournon, Nicholson's *Journal*, iv. 220.

† Ibid. p. 222.

‡ Kirwan, ii. 207.

Genus III. Species III.

which are isosceles triangles *. Sometimes the pyramids are truncated, and even altogether wanting. The crystals of this ore are often acicular.

Properties.

Its colour is commonly green; sometimes yellowish or brownish, or greyish white; sometimes a fine yellow. Streak commonly greenish white. Powder yellowish. External lustre, waxy, 2 to 3. Somewhat transparent, except when its colour is greyish white. Hardness 5 to 6. Brittle. Specific gravity from 5.86 † to 6.27 ‡. Insoluble in water and sulphuric acid, and nearly insoluble in nitric acid; soluble in hot muriatic acid, with a slight effervescence §. Before the blow-pipe it easily melts on charcoal, and crystallizes on cooling: with soda the lead is in some measure reduced.

The composition of this ore was first discovered by Gahn.

Composition.

According to Fourcroy's analysis, a specimen from Erlenbach in Alsace consists of

96	phosphat of lead
2	phosphat of iron
2	water
100	

Or it contains

79	oxide of lead
1	oxide of iron
18	phosphoric acid
2	water
100 ‖	

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* *Crystal.* iii. 391.—See also Hauy's remarks on the same subject in the *Jour. de Min.* No. xxxi. 506.

† Brisson.

‡ Klaproth.

§ Fourcroy, *Ann. de Chim.* ii. 207.

‖ Ibid.

Class IV. Order VIII.

Sp. 4. Arseniat of lead *.

This ore, which has hitherto been found only in Andalusia in Spain, and always in quartz or feldspar, is in small masses. Colour meadow green, often passing into wax yellow. Lustre waxy, 2. Transparency 2. Before the blow-pipe it melts, and retains its colour, and does not crystallize on cooling. When heated to whiteness, the arsenic acid escapes, and the lead is reduced †.

Sp. 5. Arsenite of lead.

This ore, which is a compound of the white oxide of arsenic and the oxide of lead, has been lately found in a mountain near Saint-Prix, in the department of the Seione and the Loire, by Champeaux. It is in the state of silky filaments, of a fine yellow colour, slightly flexible, and very easily broken. Sometimes in greenish yellow concretions. Before the blow-pipe it is reduced, exhaling an arsenical smell ‡.

Sp. 6. Arsenio-phosphat of lead §.

This ore, which has been found in Auvergne in France, is either in masses, or crystallized in small six-sided prisms, with curvilineal faces.

Properties.

Colour yellowish green, or shews alternate layers of pale light and green. Powder yellowish. The crystals are somewhat transparent; but when massive, this ore is opaque. Hardness 5 to 7. Brittle. Specific gravity 6.8465 ‖. Soluble in hot muriatic acid, but not in nitric. When heated it decrepitates. Before the blow-pipe melts easily, effervesces, emits a white smoke, with an arsenical smell. Some particles of lead are reduced, a brown fluid remains, which crystallizes on cooling like phosphat of lead.

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* Kirwan, ii. 209.

† Proust, *Jour. de Phys.* xxx. 394.

‡ *Jour. de Min.* No. lv. 543.

§ Kirwan, ii. 210.

‖ Brisson.

Genus III. Species VII.

According to Fourcroy, from whom the whole of this description has been taken, it is composed of

65	arseniat of lead
27	phosphat of lead
5	phosphat of iron
3	water
100 [*]	

Sp. 7. Molybdat of lead [†].

This ore, which is found in Carinthia, was first mentioned in 1781 by Mr Jacquin [‡]. It occurs either in masses, or crystallized in cubic, or rhomboidal, or octahedral plates.

Properties.

Its colour is yellow. Streak white. Lustre waxy. Generally somewhat transparent. Texture foliated. Fracture conchoidal. Hardness 5 to 6. Specific gravity 5.486 [§]; when purified from its gangue by nitric acid, 5.706 [||].

Soluble in fixed alkalies and in nitric acid. Communicates a blue colour to hot sulphuric acid. Soluble in muriatic acid, and decomposed by it. Before the blowpipe decrepitates, melts into a yellowish grey mass, and globules of lead are reduced [¶].

Klaproth first proved that this ore was molybdat of lead.

Composition.

A very pure specimen, analysed by him, contained

64.42	oxide of lead
34.25	molybdic acid
98.67 [**]	

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[*] *Ann. de Chim.* ii. 23.

[†] Kirwan, ii. 212.—Klaproth, *Ann. de Chim.* viii. 103.— Hatchett, *Phil. Trans.* 1796, p. 285.

[‡] In his *Miscellanea Austriaca*, vol. ii. p. 139.

[§] Macquart. [||] Hatchett. [¶] Macquart. [**] Beitrage, ii. 275.

Class IV.
Order IX.

According to the analysis of Mr Hatchett, it is composed of . . . .

58.40	oxide of lead
38.00	molybdic acid
2.10	oxide of iron
.28	silica
98.78 [*]	

Macquart found a specimen to contain

58.74	lead
4.76	oxygen
28.00	molybdic acid
4.50	carbonat of lime,
4.00	silica
100.00 [†]	

Its gangue is carbonat of lime.

Sp. 8. Sulphat of lead [‡].

This ore, which is found in Anglesey and in Andalusia, is generally crystallized. The crystals are regular octahedrons [§], and very minute.

Colour white. Lustre 4. Transparency 4. Before the blow-pipe it is immediately reduced.

The composition of this ore was first ascertained by Dr Withering.

Sp. 9. Chromat of lead. See Order XXI. Genus I.

ORDER IX. ORES OF NICKEL.

HITHERTO nickel has been found in too small quantities to be applied to any use; of course there are, pro-

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[*] *Phil. Trans.* lxxxvi. 323.

[†] *Jour. de Min.* No. xvii. 52.

[‡] Kirwan, *Min.* ii. 211.

[§] Hauy, *Jour. de Min.* No. xxxi. 508.

erly speaking, no mines of nickel. It occurs only (as ar as is yet known) in the secondary mountains, and it ommonly accompanies cobalt. It has been found in ifferent parts of Germany, in Sweden, Siberia, Spain, France, and Britain.

Genus I. Species I.

GENUS I. ALLOYS OF NICKEL.

Sp. 1. Kupfer nickel *.

Alloy of nickel and arsenic.

This, which is the most common ore of nickel, occurs either massive or disseminated, but never crystallized.

Properties.

Colour often that of copper, sometimes yellowish white or grey. Recent fracture often silver white. Lustre metallic, 2 to 3. Texture compact. Hardness 8. Specific gravity 6.6086 to 6.6481 †. Soluble in nitric and nitro-muriatic acids. Solution green. Before the blow-pipe exhales an arsenical smoke, and melts into a bead; which darkens by exposure to the air. This ore, when pure, is merely an alloy of nickel and arsenic; but it frequently contains cobalt and iron, and always a portion of pyrites.

GENUS II. OXIDES OF NICKEL.

Sp. 1. Nickel ochre ‡.

This mineral occurs either in the form of a powder, or indurated, and then is either amorphous, or crystallized in acicular-form crystals. The powder is generally found on the surface of other nickel ores.

Properties.

Colour different shades of green. Lustre 1 to 0. Texture earthy. Specific gravity considerable. Slowly

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* Kirwan, ii. 286.

† Brisson.

‡ Kirwan. ii. 284.

dissolves in acids: solution green. Before the blowpipe does not melt; but gives a yellowish or reddish brown tinge to borax.

This ore often contains sulphat of nickel, which is soluble in water. The solution, when evaporated, gives oblong rhomboidal crystals, from which alkalies precipitate a greyish green oxide. This oxide is soluble by acids and by ammonia. The acid solution is green; the alkaline blue.

GENUS III. SALTS OF NICKEL.

Sp. 1. Arseniat of nickel *.

This ore, which was lately discovered at Regendorff by Mr Gmelin, is found in shapeless masses, and is often mixed with plates of sulphat of barytes.

Properties. Colour pale grey, here and there mixed with pale green. Streak white. Lustre 0. Texture compact. Hardness 7. Difficultly frangible. Specific gravity considerable. Adheres slightly to the tongue, and gives an earthy smell when breathed on. Soluble in hot nitric and muriatic acids: solution green.

Contains some cobalt and alumina. The green efflorescence which appears on kupfer nickel is arseniat of nickel.

ORDER X. ORES OF ZINC.

ORES of zinc are very abundant; they generally accompany lead ores, particularly galena. Calamine, or oxide of zinc, has never been discovered in the primitive mountains.

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* Kirwan, ii. 285.

GENUS I. SULPHURETS OF ZINC.

Genus I. Species I.

Sp. 1. Blende[*].—*Sulphurated oxide of zinc.*

This ore very commonly acccompanies sulphuret of lead. It occurs both in amorphous masses and crystallized. The primitive form of its crystals is a rhomboidal dodecahedron, consisting of a six-sided prism, terminated by three-sided pyramids. All the faces of the crystals are equal rhombs. This dodecahedron may be mechanically divided into four equal rhomboidal parallelopipeds, and each of these into six tetrahedrons, whose faces are equal isosceles triangles. The figure of its integrant particles is the tetrahedron, similar to these[†].

Crystals.

The principal varieties of its crystals are the tetrahedron; the octahedron; the octahedron with its edges wanting; a 24-sided crystal, 12 of whose faces are trapezoids, and 12 elongated triangles; and, lastly, a 28-sided figure, which is the last variety, augmented by four equilateral triangles[‡].

Properties.

Colour yellow, brown, or black. Streak reddish, brownish, or grey. Lustre commonly metallic. Generally somewhat transparent. Texture foliated. Hardness 6 to 8. Specific gravity 3.93[§] to 4.1665[||]. Before the blow-pipe decrepitates, and gives out white flowers of zinc, but does not melt. Borax does not affect it. When breathed upon, loses its lustre, and recovers it very slowly[¶].

Varieties.

Variety 1. Yellow blende.—Colour commonly sulphur yellow, often passing into olive green or brownish red. Powder pale yellow. Streak yellowish or

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[*] Kirw. ii. 238.—Berg. ii. 329.

[†] See Hauy, Ibid. and Romé de Lisle, iii. 65.

[‡] Hauy, *Jour. de Min.* No. xxxiii. 669.

[§] Gellert.

[||] Brisson.

[¶] Hauy, *Jour. de Min.* No. xxxiii. 669.

Class IV.
Order X.

reddish grey, not metallic. Lustre metallic. Transparency 2 to 4. Often phosphoresces when scraped or rubbed[*].

According to Bergman, it is composed of

64	zinc
20	sulphur
5	iron
4	fluor acid
1	silica
6	water
100[†]	

Variety 2. Brown blende. Colour different shades of brown. Surface often tarnished. Powder brownish grey. Streak reddish or yellowish grey, not metallic. Lustre commonly metallic. Transparency 0 to 2.

A specimen of this variety, analysed by Bergman, contained . . . . . .

44	zinc
17	sulphur
24	silica
5	iron
5	alumina
5	water
100[*]	

Variety 3. Black blende.—Colour black, or brownish black; surface often tarnished blue; tips of the crystals often blood red Powder brownish black. Streak reddish, brownish, or grey. Lustre common or metallic. Transparency 0 to 1; the red parts 2. Hardness 8.

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[*] Bergman, ii. 345.

[†] Ibid. 347.

[‡] Ibid. 333.

Genus II.
Species I.

A specimen of this variety, analysed by Bergman, contained . . . . .

52	zinc
26	sulphur
4	copper
8	iron
6	silica
4	water
100[*]	

GENUS II. OXIDES OF ZINC.

Sp. 1. White oxide of zinc[†].

Calamine.

Crystals.

This ore is either found loose, or in masses, or crystallized. The primitive form of its crystals appears, from the mechanical division of one of them by Mr Hauy, to be an octahedron composed of two four-sided pyramids, whose sides are equilateral triangles[‡]. But the crystals are minute, and their figure not very distinct. They are either four or six sided tables with bevelled edges, six-sided prisms, or three-sided pyramids.

Properties.

Colour commonly white, grey, or yellow. Lustre often 0, sometimes 2 or 1. Opaque. The crystals are somewhat transparent. Hardness from 4 to 9, sometimes in powder. Specific gravity from 2.585 to 3.674[§]. When heated, becomes electric, without friction, like the tourmaline[||]. Not blackened by sulphuret of ammonia. Soluble in sulphuric acid. Before the blow-pipe decrepitates, and does not melt.

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[*] Bergman, ii. 335.

[†] Kirwan, ii. 233.—Bergman, ii. 321.

[‡] *Jour. de Min.* No. xxxii. 596.

[§] Kirwan.

[||] Hauy, *Jour. de Min.* No. xxxii. 596.

Composition.

This ore consists of oxide of zinc more or less contaminated with iron, silica, lime, and other foreign ingredients. In one specimen Bergman found the following ingredients: 84 oxide of zinc
3 oxide of iron
12 silica
1 alumina
100*

In another specimen, which gelatinized with acids, like zeolite, Klaproth found 66 oxide of zinc
33 silica
99

In another specimen, analysed by Pelletier, the contents were . . . . . 52 silica
36 oxide of zinc
12 water
100†

Mr Kirwan has divided this species into three varieties.

Varieties.

Variety 1. Friable calamine.—In masses which easily crumble between the fingers. Lustre 0. Opaque. Texture earthy. When its colour is white, it is pure oxide of zinc; when yellow, it is mixed with oxide of iron. The white often becomes yellow when placed in a red heat, but resumes its colour on cooling. Common in China, where it is called *wohan* or *ore of Tutenago*.

Variety 2. Compact calamine.—Colour different

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* Bergman, ii. 323.

† *Jour. de Phys.* xx. 428.

Genus III.
Species II.

hades of grey; sometimes yellow or brownish red. Lustre 0. Opaque. Texture compact.

Variety 3. Striated calamine.—This variety alone is ound crystallized; but, like the others, it is also often morphous. Colour white, and also various shades of rey, yellow, and red. Somewhat transparent. Texture triated. Lustre 2 to 1.

GENUS III. SALTS OF ZINC.

Sp. 1. Sulphat of zinc.

This salt is usually in a state of solution, and therefore belongs properly to mineral waters. Its properties have been described in the First Part of this Work.

Sp. 2. Carbonat or zinc.

This species possesses the external character of calamine, but differs from that ore in containing carbonic acid. It is soluble with effervescence in nitric and muriatic acids *.

ORDER XI. ORES OF ANTIMONY.

ORES of antimony are found abundantly in Germany, Hungary, France, Spain, Britain, Sweden, Norway, &c. They often accompany galena and hæmatites. They are found both in the secondary and primitive stratified mountains. Their gangue † is often quartz and sulphat of barytes.

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* Fourcroy, v. 367.

† The word *gang* is used by German mineralogists to denote a metallic vein. Now, it is not often that these veins consist entirely of *ore;* in general they contain stony matter besides. For instance, in the copper mine at Airthry, near Stirling, the copper ore is merely a narrow stripe in the middle of the vein, and the rest of it is filled up with sulphat of

Class IV.
Order XI.

GENUS I. ALLOYS OF ANTIMONY.

Sp. 1. Native antimony *.

This mineral, which was first discovered by Dr Swab, has been found in Sweden, France, and different parts of Scotland, both in masses and kidney-shaped lumps.

Properties.

Colour white, between that of tin and silver. Lustre metallic. Texture foliated. Hardness 6. Specific gravity above 6. Deflagrates with nitre. Before the blow-pipe melts and evaporates, depositing a white oxide of antimony.

It consists of antimony alloyed with 3 or 4 *per cent.* of arsenic.

GENUS II. SULPHURETS OF ANTIMONY.

Sp. 1. Grey ore of antimony †.

This ore, which is the most common, and indeed almost the only ore of antimony, occurs both massive, disseminated, and crystallized.

Crystals.

Its crystals are four-sided prisms, somewhat flattened, whose sides are nearly rectangles, terminated by short four-sided pyramids, whose sides are trapeziums ‡. Sometimes two of the edges are wanting, which renders the prism six-sided §.

Properties.

Colour grey. Lustre metallic. Streak grey, metallic, and brighter. Powder black or greyish black. Hardness 6 to 7. Specific gravity from 4.1327 to 4.516 ¶. Often stains the fingers. Before the blow-pipe melts easily, burns with a blue flame, and deposits a white

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barytes. We use the word *gangue* (as the French do), to denote, not the *metallic* vein, but the *stony* matter which accompanies the ore in the vein. The gangue of the copper ore at Airthry is sulphat of barytes.

[*] Kirwan, ii 245.

[†] Ibid. 247.

[‡] Romé de Lisle, iii 49.

[§] Ibid.—See also Hauy, *Jour. de Min.* No. xxxii. 606.

[¶] Brisson.

Genus II. Species I.

oxide on the charcoal. When placed in an open vessel, over a slow fire, the sulphur evaporates, and leaves a grey oxide of antimony. This oxide, if fused with tartar, is reduced.

This ore, when taken out of the mine, almost always contains a large proportion of quartz or other stony matter. When pure, it is composed of about

74 antimony
26 sulphur

100

Varieties.

Werner has divided this species into three varieties.

Variety 1. Compact sulphuret.—Colour bluish grey, urface often tarnished, and then it is blue or purplish. Lustre 1 to 2. Texture compact. Fracture fine grained, uneven. Powder black, dull, and earthy. Slightly tains the fingers.

Variety 2. Foliated sulphuret.—Colour light steel rey. Lustre 3 to 4. Texture foliated. Powder as hat of the last variety.

Variety 3. Striated sulphuret. Colour dark steel rey, and light bluish grey; surface often tarnished, nd then it is dark blue or purplish. Lustre 3 to 2. Texture striated. Powder greyish black. This variety lone has been hitherto found crystallized.

Sp. 2. Red antimonial ore [*].

Hydrosulphuret of antimony.

This species is generally found in cavities of sulphuated antimonial ore. It is crystallized in delicate eedles, often diverging from a common centre.

Colour red. Lustre 2, silky. Specific gravity 4.7.

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[*] Kirwan, ii. 250.

Class IV. Order XI.

Before the blow-pipe melts easily, and evaporates with a sulphureous smell.

This ore has not been analysed. Mineralogists have supposed it to be a natural kermes. If so, we may conclude, from the experiments of Berthollet *, that it is a hydrosulphuret of antimony, and consequently composed of oxide of antimony, sulphur, and sulphurated hydrogen gas.

Sp. 3. Plumose antimonial ore †.

Sulphurets of antimony and arsenic.

This species, which is sometimes found mixed with the crystals of sulphurated antimony, is in the form of brittle, capillary, or lanuginous crystals, often so small that they cannot be distinctly seen without a microscope.

Properties.

Colour steel or bluish grey, often tarnished, and then brown or greyish black. Lustre 1, semimetallic. Before the blow-pipe emits a smoke, which deposits a whitish and yellowish powder on the charcoal: it then melts into a black slag.

It is supposed to consist of sulphur, antimony, arsenic, and some silver.

GENUS III. OXIDES OF ANTIMONY.

There is a substance found incumbent on sulphuret of antimony, of a yellow colour, and an earthy appearance, which has been supposed an oxide of antimony, and denominated antimonial ochre. But hitherto it has not been analysed.

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* *Ann. de Chim.* xxv. 259.

† Kirwan, ii. 250.

GENUS IV. SALTS OF ANTIMONY.

Genus IV. Species I.

Sp. 1. Muriat of antimony [*].

This ore, which has been found in Bohemia, is some-imes in quadrangular tables; sometimes in acicular :rystals grouped like zeolites; and sometimes in prisms.

Properties.

Colour pale yellowish or greyish white. Lustre 3 to , nearly metallic. Transparency 2. Texture foliated. Aelts easily by the flame of a candle, and emits a vhite vapour [†]. Before the blow-pipe decrepitates; vhen powdered, and just ready to melt, it evaporates, nd leaves a white powder around. Between two pieces f coal it is reducible to a metallic state.

ORDER XII. ORES OF BISMUTH [‡].

BISMUTH has been found only in the primitive iountains, and is by no means common. When unac-ompanied by any other metal, it does not form veins, ut kidney-form masses. It often accompanies cobalt. s gangue is commonly quartz. Its ores are not very undant. They have been found chiefly in Sweden, orway, Transylvania, Germany, France, and England.

GENUS I. ALLOYS OF BISMUTH.

Sp. 1. Native bismuth [§].

This mineral, which is found at Shneeberg, Johan-:orgenstadt, &c. in Germany, has commonly the form small plates lying above one another. Sometimes it crystallized in four-sided tables, or indistinct cubes.

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[*] Kirwan, ii. 251.

[†] Hauy, *Jour de Min.* No. xxxii. 609.

[‡] Pott, *Observ. Chym.* 134.—Geoffroy, *Mem. Par.* 1753, p. 296.

[§] Kirwan, ii. 264.

Class IV. Order XII.

Colour white with a shade of red; surface often tarnished red, yellow, or purple Lustre metallic, 3 to 2. Opaque. Texture foliated or striated. Hardness 6. Specific gravity 9.022[*] to 9.57[†]. Exceedingly fusible. Before the blow-pipe gives a silvery white bead, and at last evaporates in a yellowish white smoke, which is deposited on the charcoal.

It is generally accompanied by cobalt, and sometimes contains arsenic.

GENUS II. SULPHURETS OF BISMUTH.

Sp. 1. Common sulphuret of bismuth[‡].

This ore, which is found in Sweden, Saxony, and Bohemia, occurs sometimes in amorphous masses, and sometimes in needleform crystals.

Properties.

Colour commonly bluish grey, sometimes white; surface often tarnished yellow, red, and purple. Powder black and shining. Lustre metallic, 2 to 3. Streak obscurely metallic. Texture foliated. Hardness 5. Brittle. Specific gravity 6.131[§] to 6.4672[||]. When held to the flame of a candle, it melts with a blue flame and sulphureous smell. Before the blow-pipe emits a reddish yellow smoke, which adheres to the charcoal. This powder becomes white when it cools, and resumes its former colour when the flame is directed upon it[¶].

Composition.

This ore, according to Sage, contains 60 bismuth.
And according to La Perouse, it holds 36 sulphur

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[*] Brisson.

[†] Kirwan.

[‡] Kirwan, ii. 266.—Sage, *Mem. Par.* 1782, 307.

[§] Kirwan.

[||] Brisson.

[¶] Gillot, *Jour. de Min.* No. xxxii. 585.

Genus I.
Species I.

A specimen, analysed by Klaproth, contained

95 bismuth
5 sulphur

100 *

It is commonly accompanied by quartz, asbestus, or sparry iron ore.

Genus III. Oxides of Bismuth.

Sp. 1. Yellow oxide of Bismuth †.

Bismuth ochre.

This ore generally accompanies the two species already described. It is found in two states; either of an earthy consistence, or crystallized in cubes or quadrangular plates.

Colour usually greenish yellow, sometimes grey. Soluble in nitrous acid without effervescence, and may in a great measure be precipitated by the affusion of water.

Order XIII. ORES OF TELLURIUM.

Hitherto tellurium has only been found in Transylvania. It occurs in three different mines; that of Fatzbay, Offenbanya, and Nagyag; which are considered as gold mines, because they contain less or more of that metal. Its gangue is commonly quartz.

Genus I. Alloys of Tellurium.

Sp. 1. White gold ore of Fatzbay.

Alloy of tellurium and iron with some gold.

This species is generally massive. Its colour is be-

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* Beitrage, i. 256.

† Kirwan, ii. 265.

tween tin white and lead grey. Lustre considerable, metallic. Texture granular*.

Composition.

According to Klaproth's analysis, it is composed of

72.0	iron
25.5	tellurium
2.5	gold
100.0†	

Sp. 2. Graphic golden ore of Offenbanya.

Tellurium alloyed with gold and silver.

This ore is composed of flat prismatic crystals; the arrangement of which has some resemblance to Turkish letters. Hence the name of the ore.

Properties.

Colour tin white, with a tinge of brass yellow‡. Lustre metallic, 3. Hardness 4 to 5. Brittle. Specific gravity 5.723. Before the blow-pipe decrepitates, and melts like lead. Burns with a lively brown flame and disagreeable smell, and at last vanishes in a white smoke, leaving only a whitish earth§.

Composition.

According to Klaproth's analysis, it is composed of

60	tellurium
30	gold
10	silver
100‖	

The yellow gold ore of Nagyag would belong to this species were it not that it contains lead. Its composition, according to Klaproth's analysis, is as follows:

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* *Ann. de Chim.* xxv. 327.

† Ibid. 280.

‡ Ibid. 328.

§ De Born, Kirwan, ii. 101.

‖ *Ann. de Chim.* xxv. 280.

Genus I.
Species III.

45.0 tellurium
27.0 gold
19.5 lead
8.5 silver

100.0 and an atom of sulphur *

Sp. 3. Grey foliated gold ore of Nagyag.

This ore is found in plates of different degrees of thickness, adhering to one another, but easily separable: these are sometimes hexahédral, and often accumulated so as to leave cells between them.

Properties.

Colour deep lead grey, passing to iron black, spotted. Lustre metallic, moderate. Texture foliated; leaves slightly flexible †. Hardness 6. Specific gravity 8.919. Stains the fingers. Soluble in acids with effervescence ‡.

Composition.

According to Klaproth, it is composed of

50.0 lead
33.0 tellurium
8.5 gold
7.5 sulphur
1.0 silver and copper

100.0 §

ORDER XIV. ORES OF ARSENIC.

ARSENIC is scattered in great abundance over the mineral kingdom, accompanying almost every other metal, and forming also sometimes peculiar veins of its own. Of course it occurs in almost every species of mountain, and is accompanied by a variety of gangues.

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* *Ann. de Chim.* xxv. 280.

† Klaproth, Ibid. p. 329.

‡ De Born, Kirwan, ii. 99.

§ *Ann. de Chim.* xxv. 280.

Class IV.
Order XIV.

GENUS I. ALLOYS OF ARSENIC.

Sp. 1. Native arsenic[*].

This mineral is found in different parts of Germany. It occurs generally in masses of various shapes, kidney-form, botryoidal, &c.

Properties. Colour that of steel. Its surface quickly becomes tarnished by exposure to the air. Lustre metallic (when fresh), 3 to 2. Streak bluish grey, metallic, and bright. Powder dull and black. Texture compact. Hardness 7 to 8. Brittle. Specific gravity 5.67[†] to 5.7249[‡]. Gives an arsenical smell when struck. Before the blow-pipe emits a white smoke, diffuses a garlic smell, burns with a blue flame, gradually evaporates, depositing a white powder.

It is always alloyed with some iron[§], and often contains silver, and sometimes gold.

GENUS II. SULPHURETS OF ARSENIC.

Sp. 1. Realgar[||].

This mineral is found in Sicily, about Mount Vesuvius, in Hungary, Transylvania, and various parts of Germany. It is either massive or crystallized.

Crystals. The primitive form of the crystals is, according to Romé de Lisle, a four-sided rhomboidal prism, terminated by four-sided pyramids, the sides of which are rhombs[¶]. It commonly appears in 4, 6, 8, 10, or 12 sided prisms, terminated by four-sided summits[**].

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[*] Kirwan, ii. 255.

[†] Kirwan.

[‡] Brisson.

[§] De Born, *Catal.* of M. Raab, ii. 194.

[||] Kirwan, ii. 261.—Bergman, ii. 297.

[¶] *Crystall.* iii. 34.

[**] Ibid.

Genus II.
Species II.
Properties.

Colour red. Streak yellowish red. Powder scarlet. ustre 3 to 2. Transparency from 2 to 3; sometimes Hardness 5 to 6. Specific gravity 3.3384[*]. It an electric *per se*, and becomes negatively electric by iction[†]. Nitric acid deprives it of its colour. Be- ıre the blow-pipe it melts easily, burns with a blue ıme and garlic smell, and soon evaporates.

Sp. 2. Orpiment[‡].

Auripigmentum.

This ore, which is found in Hungary, Wallachia, eorgia, and Turkey in Asia, is either massive or cry- allized. The crystals are confused, and their figure ınnot be easily determined; some of them appear oc- ıhedrons, and others minute four-sided prisms.

Properties.

Its colour is yellow. Streak orange yellow. Lustre axy, 2 to 3. Transparency from 0 to 2. Texture ıliated, Hardness 4 to 8. Specific gravity from .048[§], to 3.521[‖]. Effervesces with hot nitric acid. urns with a bluish white flame. Before the blow- ipe melts, smokes, and evaporates, leaving only a little ırth and some traces of iron.

GENUS III. OXIDES OF ARSENIC.

Sp. 1. White oxide of arsenic[¶].

Native calx of arsenic.

This ore is found in various parts of Germany, Hun- ary, &c. either in powder, or massive, or crystallized ı prismatic needles.

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[*] Brisson.

[†] Hauy, *Jour. de Min.* No. xxxii. 612.

[‡] Kirwan, ii 260.—*Alberti de Auripigmento.*—Scopoli in anno 5to *Hist. at.* p. 5.—Bergman, ii. 297.

[§] Kirwan.

[‖] Gellert.

[¶] Kirwan, ii 258.—Bergman, ii. 285.

Colour white or grey, often with a tint of red, yellow, green, or black. Lustre common, 1 to 2. Transparency 1 to 0; when crystallized, 2. Texture earthy. Hardness 6. Brittle. Specific gravity 3.7*. Soluble in hot diluted nitric acid without effervescence. Soluble at 60° Fahrenheit in 80 times its weight of water. Before the blow-pipe sublimes, but does not inflame. Tinges borax yellow.

GENUS IV. SALTS.

Sp. 1. Arseniat of lime.—See Class I. Order II. Genus I.

Sp. 2. Arseniat of copper.—See Class IV. Order V. Genus IV.

Sp. 3. Arseniat of iron.—See Class IV. Order VI. Genus VI.

Sp. 4. Arseniat of lead.—See Class IV. Order VIII. Genus III.

Sp. 5. Arseniat of nickel.—See Class IV. Order IX. Genus III.

Sp. 6. Arseniat of cobalt.—See Class IV. Order XV. Genus IV.

ORDER XV. ORES OF COBALT.

Cobalt ores are found almost exclusively in the stratified mountains, except one species, sulphuret of cobalt, which affects the primitive mountains. They are not very abundant; and for that reason cobalt is more valuable than many of the other metals which have been already treated of. They are commonly accompanied

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* Kirwan.

nickel, bismuth, or iron. They are most abundant Germany, Sweden, Norway, and Hungary; they have en found also in Britain and France, but not in any eat quantity.

Genus I.
Species I.

GENUS I. ALLOYS OF COBALT.

Sp. 1. Cobalt alloyed with arsenic *.

Dull grey cobalt ore.

This ore, which occurs in different parts of Germa- y, is either amorphous or crystallized. The forms of crystals are the cube; sometimes the cube with its gles, or edges, or both wanting; and the octahe- on †.

Properties.

Its colour, when fresh broken, is white or bluish ey, sometimes with a shade of red; when exposed to e air it soon becomes tarnished. Streak bluish grey d metallic. Lustre scarcely metallic, 0 to 1. Tex- re compact. Hardness 10. Difficultly frangible. Spe- fic gravity, when amorphous, 5.309 to 5 571 ‡; when ystallized 7.7207 §. When struck it gives out an ar- nical smell. Before the blow pipe it emits an ar- nical vapour, becomes magnetic, and melts easily, un- ss it contains a great quantity of iron. Tinges borax ark blue, and a small metallic bead is obtained.

Composition.

A specimen of this ore from Cornwall, examined by Ir Klaproth, contained 20 cobalt
24 iron
33 arsenic
—
77
ith some bismuth and stony matter ||.

---

* Kirwan, ii. 270.
† Rome de Lisle, iii. 123.
‡ Kirwan, ii. 270.
§ Hauy, *Jour. de Min.* No. xxxii. 588.
|| Klaproth's *Cornwall*, p. 61.

Class IV.
Order XV.

Genus II. Sulphurets of Cobalt.

Sp. 1. White cobalt ore *.

Sulphuret of cobalt, arsenic, and iron.

The descriptions which different mineralogists have given of this ore are so various, that it is impossible not to suppose that distinct substances have been confounded together.

It occurs either in masses, or crystallized in cubes, dodecahedrons, octahedrons, and icosahedrons.

Propertias.

Colour tin white, sometimes tarnished reddish or yellowish. Powder steel grey. Lustre partly metallic, and from 2 to 4; partly 0 or 1. Texture foliated Hardness 8 to 9. Specific gravity from 6.284 † to 6.4509 ‡. Before the blow-pipe generally gives out an arsenical vapour, and does not melt.

Composition.

The analyses that have been given of this ore are very various. Sometimes it has been found to contain no arsenic nor iron, and sometimes to contain both. A specimen from Tunaberg in Sweden, which ought to belong to this species, was analysed by Tassaert, and found to consist of . . 49.0 arsenic
36.7 cobalt
5.6 iron
6.5 sulphur

97.8 §

Klaproth found a specimen of the same ore to contain . . . . 55.5 arsenic
44.0 cobalt
0.5 sulphur

100.0 ||

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[*] Kirwan, ii. 273.—Sage *Jour. de Phys.* xxxix. 53.

[†] Kirwan.

[‡] Hauy.

[§] *Ann. de Chim.* xxviii. 100.

[||] Beitrage, ii. 307.

Genus III.
Species I.

GENUS III. OXIDES OF COBALT.

Sp. 1. Black cobalt ore or ochre *.

This ore, which occurs in different parts of Germany, is either in the form of a powder, or indurated.

Colour black, often with a shade of blue, grey, brown, or green. Lustre 0 to 1. Streak brighter. Hardness (of the indurated) from 4 to 8. Specific gravity 3 to 4. Soluble in muriatic acid. Tinges borax blue.

Sp. 2. Brown cobalt ore †.

Colour greyish or dark leather brown. Streak brighter, unctuous. Communicates a pale blue tinge in fusion.

Sp. 3. Yellow cobalt ore ‡.

Colour yellow. Dull and earthy. Hardness 4 to 5. Texture earthy. Streak brighter, unctuous. Gives a weak blue tinge.

GENUS IV. SALTS OF COBALT.

Sp. 1. Arseniat of cobalt §.

Red cobalt ore.

This species, like most other ores of cobalt, has neither been accurately described nor analysed.

It is found in masses of various shapes, and crystallized in quadrangular tables or acicular prisms.

Properties.

Colour red. Lustre from 2 to 3, sometimes 0. Transparency 0 to 2. Hardness 5 to 7. Brittle. Before the blow-pipe becomes blackish grey. Diffuses a weak arsenical smell. Tinges borax blue.

Sp. 2. Sulphat of cobalt.

This salt has been found in Neusohl in Hungary in the form of transparent stalactites, of a red colour.

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* Kirwan, ii. 275. † Ibid, 276. ‡ Ibid. § Ibid. 278.

Some mineralogists considered these stalactites as sulphat of manganese; others as sulphat of cobalt. Klaproth found, by analysis, that the latter opinion is the true one *.

ORDER XVI. ORES OF MANGANESE †.

ORES of manganese occur often in strata, both in the primitive and secondary mountains; scarcely ever, however, I believe, in those mountains which are considered as the most ancient of all. They are very common, having been found abundantly in Germany, France, Spain, Britain, Sweden, Norway, Siberia, and other countries.

GENUS I. OXIDES OF MANGANESE.

Hitherto manganese has only been found in the state of oxide. La Perouse, indeed, suspected that he had found it in a metallic state: but probably there was some mistake or other in his observations.

Sp. 1. Oxide of manganese combined with barytes.

This species, which exists in great abundance in Romaneche near the river Soane in France, is found massive, forming a stratum in some places more than 12 feet thick.

Properties.

Colour greyish black or brownish black, of great intensity. Lustre, external, 0; internal, metallic, 1. Soon tarnishes by exposure to the air, and then becomes

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* Beitrage, ii. 320.

† Pott, *Miscelan. Berolens*, vi. 40.—Margraff, *Mem. Berlin*, 1773, p. 3.—La Perouse, *Jour. de Phys.* xvi. 156. and xv. 67. and xxviii. 68.—Sage, *Mem. Par.* 1785, 235.

Genus. I.
Species II.

tensely black. Texture granular. Fracture uneven; metimes conchoidal. Often porous. Hardness 11. ifficultly frangible. Specific gravity from 3.950 to 10. Absorbs water. When taken out of water af- r a minute's immersion, it has a strong argillaceous nell. Conducts electricity nearly as well as if it were a metallic state. Infusible by the blow-pipe. Tin- s soda red; the colour disappears before the blue ne of flame, and is reproduced by the action of the ellow flame.

Composition.

From the analysis of Vauquelin, it appears that it is omposed of . . . . 50.0 white oxide of manganese
33.7 oxygen
14.7 barytes
1.2 silica
.4 charcoal

100.0 *

Sp. 2. Grey ore of manganese †.

This ore occurs both massive and disseminated; it is lso sometimes crystallized in slender four-sided prisms r needles.

Properties.

Colour usually dusky steel grey; sometimes whitish grey or reddish grey. Streak and powder black. Ex- ernal lustre 3 to 2; internal metallic, 2 to 1. Texture striated or foliated. Hardness 4 to 5. Brittle. Spe- cific gravity from 4.073 ‡ to 4.8165 §. Before the blow-pipe darkens; tinges borax reddish brown.

A specimen of oxide of manganese from the moun- tains of Vosges, which probably belonged to this species,

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* Dolomieu, *Jour. de Min.* No. xix. 42.

† Kirwan, ii. 291.

‡ Vauquelin.

§ Brisson.

Class IV. Order XVI.

Composition.

and which was analysed by Vauquelin, was composed of

82	oxide of manganese
7	carbonat of lime
6	silica
5	water
100*	

Sometimes it contains a little barytes and iron.

Sp. 3. Black or brown ore of manganese†.

Properties.

This ore is found sometimes in the state of powder, and sometimes indurated in amorphous masses of various figures. Colour either black, sometimes with a shade of blue or brown, or reddish brown. Streak of the harder sorts metallic; of the others black. Lustre 0 to 1; internal (when it is indurated), metallic. Texture compact. Hardness 5 to 7. Specific gravity 3.7076 to 3.9039; that of the powdery sometimes only 2. Before the blow-pipe it exhibits the same phenomena as the last species.

Composition.

A specimen of this ore, analysed by Westrum, contained . . . .

45.00	manganese
14.00	oxide of iron
11.00	silica
7.25	alumina
2.00	lime
1.50	oxide of copper
18.00	air and water
98.75	

---

* *Jour. de Min.* No. xvii. 13.

† Kirwan, ii. 292.—Wedgewood, *Phil. Trans.* lxxiii. 284.

GENUS II. SALTS OF MANGANESE.

Genus II.
Species I.

Sp. 1. Carbonat of manganese*.

White ore of manganese.

This species occurs in Sweden, Norway, and Tran-
lvania. It is either in the form of loose scales, or
ssive, or crystallized in needles.

Properties.

Colour white, or reddish white. Texture either ra-
ted or scaly. Lustre of the scaly 2. Transparency
o 2. Hardness of the massive 6 to 9. Specific gra-
y 2.794. Effervesces with mineral acids. Heated
redness, blackens. Tinges borax violet.

Sp. 2. Red ore of manganese†.

Carbonat of manganese and iron.

This species has been found in Piedmont and in the
renees. It is sometimes in powder, sometimes mas-
e, sometimes crystallized in rhomboidal prisms or
edles.

Properties.

Colour pale rosy red, mixed with white. Powder
rly white. Lustre 0. Transparency 1. Hardness
Specific gravity 3.233. Effervesces with nitric
l muriatic acids. When heated to redness becomes
dish brown. Tinges borax red.

Composition.

A specimen, analysed by Ruprecht, contained

55	silica
35	oxide of manganese
7	oxide of iron
1.5	alumina
98.5‡	

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[*] Kirwan, ii. 297.

[†] Kirwan, ii. 297.—Napion, *Mem. Turin*, iv. 303.

[‡] *Jour. de Phys.* xxxi. 22.

Class IV.
Ord. XVII.

ORDER XVII. ORES OF TUNGSTEN.

ORES of tungsten are by no means common. They have hitherto been found only in the primitive mountains. Their gangue is commonly quartz. They very often accompany tin ores.

GENUS I. OXIDES OF TUNGSTEN.

Sp. 1. Wolfram*.

Oxides of tungsten, iron, and manganese—Tungstat o iron and manganese.

This species is found in different parts of Germany in Sweden, Britain, France, and Spain; and is almos constantly accompanied by ores of tin. It occurs both massive and crystallized. The primitive form of its crystals, according to the observations of Mr Hauy, is a rectangular parallelopiped, whose length is 8.66, whose breadth is 5, and thickness 4.33†. It is not common however, to find crystals of this perfect form; in many cases, the angles, and sometimes the edges, of the crystal are wanting; owing, as Mr Hauy has shewn, to the superposition of plates, whose edges or angles decrease according to a certain law‡.

Crystals.

Properties.

Colour brown or brownish black. Streak reddish brown. Powder stains paper with the same colour Lustre external, 2; internal, 2 to 3; nearly metallic Texture foliated. Easily separated into plates by percussion. Hardness 6 to 8. Specific gravity from 7.006§

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[*] Kirwan, ii. 316.—De Luyart, *Mem. Thoulouse*, ii. 141.—Gmelin, Crell's *Jour.* Eng. Trans. iii. 127. 205. and 293.—La Perouse, *Jour. de Min.* No iv. p 23.

[†] *Jour. de Min.* No. xix. 8.

[‡] Ibid.

[§] Kirwan.

Genus I. Species II.

to 7.333*. Moderately electric by communication. Not magnetic. Infusible by the blow-pipe. Forms with borax a greenish globule, and with microcosmic salt a transparent globule of a deep red†.

Composition.

The specimen of this ore, examined by Messrs d'Elhuyarts, was composed of 65 oxide of tungsten
22 oxide of manganese
13 oxide of iron

100

Another specimen from Puy-les-Mines in France, analysed by Vauquelin and Hecht, contained
67.00 oxide of tungsten
18.00 black oxide of iron
6.25 black oxide of manganese
1.50 silica
7.25 oxide of the iron and manganese

100.00 ‡

Sp. 2. Tungstat of lime §.

Tungsten.

This ore, which is now exceedingly scarce, has hitherto been found only in Sweden and Germany. It is either massive or crystallized; and, according to Hauy, the primitive form of its crystals is the octahedron ¶.

Properties.

Colour yellowish white or grey. Lustre 3 to 2. Transparency 2 to 3. Texture foliated. Hardness 6 to 9. Specific gravity 5.8 to 6.0665. Becomes yel-

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* Hauy. † Vauquelin, *Jour. de Min.* No. xix. 11. ‡ Ibid.

§ Kirwan, ii. 314.—Scheele's Works (French Transl.), ii. 81.—Bergman, Ibid. p. 94.—Crell, *Chem. Annalen*, 1784, 2 Band. 195.

¶ *Jour. de Min.* No. xxxiii. 657.

low when digested with nitric or muriatic acid. Infusible by the blow-pipe. With borax forms a colourless glass, unless the borax exceed, and then it is brown. With microcosmic salt it forms a blue glass, which loses its colour by the yellow flame, but recovers it in the blue flame*.

Composition.

It is composed of about 70 oxide of tungsten
30 lime

100

with a little silica and iron†.

Sp. 3. Brown tungstat of lime.

This ore is found in Cornwall, and is either massive or composed of small crystalline grains.

Properties.

Colour grey, variegated with yellow and brown. Lustre 2, waxy. Hardness 6 to 7. Specific gravity 5.57. Its powder becomes yellow when digested in aqua regia.

According to Klaproth, it is composed of

88 oxide of tungsten
11.5 lime

99.5

ORDER XVIII. ORES OF MOLYBDENUM.

ORES of molybdenum are very scarce, having only been found in Sweden, Germany, Carniola, among the Alps, near Inverness and in the island of Lewis in Scotland. Like tin and tungsten, it affects the primitive mountains.

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[*] Scheele and Bergman.

[†] Scheele.

Genus I.
Species I.

GENUS I. SULPHURET OF MOLYBDENUM.

Sp. 1. Common sulphuret[*].

Molybdena.

This ore, which is the only species of molybdenum ore at present known, is found commonly massive; sometimes, however, it is crystallized in hexahedral tables.

Properties.

Colour light lead grey; sometimes with a shade of red. Streak bluish grey, metallic. Powder bluish. Lustre metallic, 3 to 2. Texture foliated. Lamellæ slightly flexible. Hardness 4. Specific gravity 4.569[†] to 4.7385[‡]. Feels greasy; stains the fingers. Marks bluish black. A piece of resin rubbed with this mineral becomes positively electric[§]. Insoluble in sulphuric and muriatic acids; but in a boiling heat colours them green. Effervesces with warm nitric acid, leaving a grey oxide undissolved. Before the blow-pipe, on a silver spoon, emits a white smoke, which condenses into a white powder, which becomes blue in the internal, and loses its colour in the external flame. Scarcely affected by borax or microcosmic salt. Effervesces with soda, and gives it a reddish pearl colour.

Composed of about 60 molybdenum
40 sulphur

100[¶]

ORDER XIX. ORES OF URANIUM.

URANIUM has hitherto been found only in Germany

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[*] Kirwan, ii. 322.—Scheele's Works, i. 236. French Transl.—Pelletier, *Jour. de Phys.* xxvii. 434.—Ilsemann, Ibid. xxxiii. 292.—Sage, Ibid. 389.—Klaproth and Modeer, *Ann. de Chim.* iii. 120.

Karsten. [‡] Brisson. [§] Hauy, *Jour de Min.* xix. 70. [¶] Klaproth.

Class IV. Order XIX.

and France. The mines where it has occurred are in the primitive mountains.

GENUS I. OXIDES OF URANIUM.

Sp. 1. Pechblende*.

This ore, which has been found at Johanngeorgenstadt in Saxony, and Joachimsthal in Bohemia, is either massive or stratified with other minerals.

Properties.

Colour black or brownish black; sometimes with a shade of grey or blue. Streak darker. Powder opaque and black. Lustre semimetallic, from 3 to 1. Fracture conchoidal. Hardness 7 to 8. Very brittle. Specific gravity from 6.3785† to 7.5, and even higher‡. Imperfectly soluble in sulphuric and muriatic acids; perfectly in nitric acid and aqua regia. Solution wine yellow. Infusible with alkalies in a crucible: infusible by the blow-pipe *per se*. With borax and soda forms a grey opaque slag; with microcosmic salt, a green glass. A specimen of this ore from Joachimsthal, analysed lately by Klaproth, contained

Composition.

86.5	uranium
6.0	sulphuret of lead
5.0	silica
2.5	oxide of iron
100.0§	

Sp. 2. Yellow oxide of uranium¶.

Uranitic ochre.

This ore is generally found on the surface of the last species at Johanngeorgenstadt, and is either massive or in powder.

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[*] Kirwan, ii. 305.

[†] Morveau, *Jour. de Min.* No. xxxii. 610.

[‡] Klaproth, Beitrage, ii. 197.

[§] Beitrage, ii. 321.

[¶] Kirwan, ii. 303.

Genus I. Species III.

Colour yellow, red, or brown. Streak of the yellow orts yellow; of the red, orange yellow. Lustre 0. lightly stains the fingers. Feels meagre. Texture rthy. Hardness 3 to 4. Specific gravity 3.2438[*]. fusible by the blow-pipe; but in a strong heat beomes brownish grey.

Composed of oxide of uranium and oxide of iron.

Sp. 3. Crystallized oxide of uranium.

Green mica—Chalcolite.

Crystals.

This substance is also found at Johanngeorgenstadt, nd near Eibenstock and Rheinbreidenbach[†]. It is ometimes amorphous, but more commonly crystallized. ts crystals are square plates, octahedrons, and six-sided risms. Champeaux has found a mine of it in Burundy[‡].

Properties.

Colour green; sometimes nearly white; sometimes, hough rarely, yellowish. Streak greenish white. Lustre ; to 2; internal 2; sometimes pearly; sometimes neary metallic. Transparency 2 to 3. Texture foliated. ardness 5 to 6. Brittle. Soluble in nitric acid withut effervescence. Infusible by alkalies.

Composed of oxide of uranium, with some oxide f copper. When its colour is yellow it contains no opper.

ORDER XX. ORES OF TITANIUM.

HITHERTO titanium has been found only in the primitive mountains, the Crapacks[||], the Alpes[¶], and

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[*] Hauy, *Jour. de Min.* No. xix. 70.

[†] Gmelin.

[‡] *Jour. de Min.* No. lv. 527.

[||] Ibid. No. xii. 51.

[¶] Dolomieu, *Jour. de Min.* No. xlii. 431. & Saussure, *Voyages*, No. 1894.

Class IV. Order XX.

the Pyrenees [*]. It has been found also in Britanny [†] and in Cornwall.

Genus I. Oxides of Titanium.

Sp. 1. Red oxide of titanium.

Red shorl—Sagenite.

This ore has been found in Hungary, the Pyrenees, the Alps, and in Britanny in France. It is generally crystallized. The primitive form of its crystals, according to the observations of Mr Hauy, is a rectangular prism, whose base is a square; and the form of its molecules is a triangular prism, whose base is a right angled isosceles triangle, and the height is to any of the sides of the base about the right angle as $\sqrt{12}$ to $\sqrt{5}$, or nearly as 3 : 2 [‡]. Sometimes the crystals of titanium are six-sided, and sometimes four-sided prisms, and often they are implicated together.

Crystals.

Properties.

Colour red or brownish red. Powder brick or orange red. Lustre 3. Transparency commonly 0; sometimes 1. Texture foliated. Hardness 9. Brittle. Specific gravity from 4.18 [§] to 4.2469 [¶]. Not affected by the mineral acids. When fused with carbonat of potass, and diluted with water, a white powder precipitates, heavier than the titanium employed. Before the blowpipe it does not melt, but becomes opaque and brown. With microcosmic salt it forms a globule of glass, which appears black; but its fragments are violet. With borax it forms a deep yellow glass, with a tint of brown. With soda it divides and mixes, but does not form a transparent glass.

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[*] *Jour. de Min.* No xxxii. 614.

[†] Ibid.

[‡] *Jour. de Min.* xv. 28. and xxxii. 615.

[§] Klaproth.

[¶] Vauquelin and Hecht.

Genus I.
Species II.

When pure, it is composed entirely of oxide of titanium.

Sp. 2. Menachanite [*].

Oxide of titanium combined with iron.

This substance has been found abundantly in the valley of Menachan in Cornwall; and hence was called menachanite by Mr Gregor, the discoverer of it. It is in small grains like gunpowder, of no determinate shape, and mixed with a fine grey sand.

Properties.

Colour black. Easily pulverised. Powder attracted by the magnet. Specific gravity 4.427. Does not detonate with nitre. With two parts of fixed alkali it melts into an olive-coloured mass, from which nitric acid precipitates a white powder. The mineral acids only extract from it a little iron. Diluted sulphuric acid, mixed with the powder, in such a proportion that the mass is not too liquid, and then evaporated to dryness, produces a blue coloured mass. Before the blow-pipe does not decrepitate nor melt. It tinges microcosmic salt green; but the colour becomes brown on cooling: yet microcosmic salt does not dissolve it. Soluble in borax, and alters its colour in the same manner.

Composition.

According to the analysis of Mr Gregor, it is composed of . . . 46 oxide of iron
45 oxide of titanium
—
91 with some silica and manganese [†].

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[*] Kirwan, ii. 326.—Gregor, *Jour. de Phys.* xxxix. 72. & 152.—Schmeisser, Crell's *Annals*, Eng. trans. iii. 252.

[†] Gregor, *Jour. de Phys.* xxxix. 72. 152.

Class IV.
Order XX.

According to Mr Klaproth's analysis, it is composed of . . . .

51.00	oxide of iron
45.25	oxide of titanium
3.50	silica
.25	oxide of manganese
100.00 [*]	

Another variety of this ore from the Uralian mountains, analysed by Lowitz, contained

53	oxide of titanium
47	oxide of iron
100 [†]	

A mineral, nearly of the same nature with the one just described, has been found in Bavaria. Its specific gravity, however, is only 3.7. According to the analysis of Vaquelin and Hecht, it is composed of

49	oxide of titanium
35	iron
2	manganese
14	oxygen combined with the iron and manganese
100 [‡]	

A specimen of the same ore from Botany Bay has been lately analysed by Mr Chenevix [§].

Sp. 3. Calcareo siliceous ore of titanium.

Oxide of titanium combined with lime and silica—
Titanite [¶].

This ore has hitherto been found only near Passau.

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[*] Beitrage, ii. 231.

[†] Crell's *Annals*, 1799, i. 183.

[‡] *Jour. de Min.* No. xix. 57.

[§] Nicholson's *Jour.* v. 132.

[¶] Kirwan, ii. 331.

Genus I.
Species I.

was discovered by Professor Hunger. It is some- mes massive, but more commonly crystallized in four- ided prisms, not longer than one fourth of an inch.

Properties.

Colour reddish, yellowish, or blackish brown; some- mes whitish grey. Powder whitish grey. Lustre axy or nearly metallic, 2 to 3. Transparency from 0 2. Texture foliated. Hardness 9 or more. Brittle. pecific gravity 3.510. Muriatic acid, by repeated di- estion, dissolves one-third of it. Ammonia precipi- ates from this solution a clammy yellowish substance. nfusible by the blow-pipe, and also in a clay crucible; ut in charcoal is converted into a black opaque po- ous slag.

According to the analysis of Klaproth, it is compo- ed of . . . . . . 33 oxide of titanium
35 silica
33 lime

101 *

Order XXI. ORES OF CHROMUM.

Hitherto chromum has been found only in two places, near Ekaterinbourg in Siberia, and in the department of the Var in France. In the first of these places, and probably also in the second, its gangue is quartz.

Genus I. Salts of Chromum.

Sp. 1. Chromat of lead.—*Red lead ore of Siberia.'*

This singular mineral, which has now become scarce, is found in the gold mines of Beresof near Ekaterinbourg in Siberia, crystallized in four-sided prisms, sometimes terminated by four-sided pyramids, somtimes not.

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* Beitrage, i. 241.

Class IV. Order XXI.

Properties.

Colour red, with a shade of yellow. Streak and powder a beautiful orange yellow. Lustre from 2 to 3. Transparency 2 to 3. Structure foliated. Texture compact. Fracture uneven. Hardness 5 to 4. Specific gravity 6.0269* to 5.75†. Does not effervesce with acids. Before the blow-pipe decrepitates; some lead is reduced, and the mineral is converted to a black slag, which tinges borax green.

Composition.

According to the analysis of Vauquelin, it is composed of . . . 65.12 oxide of lead
34.88 chromic acid
100.00 ‡

Sp. 2. Chromat of iron and alumina.

This mineral, which has been found only near Gassin in the department of Var in France, is in irregular masses.

Properties.

Colour brown, not unlike that of brown blende. Powder ash grey. Lustre slightly metallic. Hardness sufficient to scratch glass. Specific gravity 4.0326. Does not melt before the blow-pipe *per se;* but melts with borax, and forms a fine green bead. Insoluble in nitric acid. Melted with potass, and dissolved in water, the solution assumes a beautiful orange yellow colour. It is composed of 43.0 chromic acid
34.7 oxide of iron
20.3 alumina
2.0 silica
100.0 §

Composition.

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* Brisson. † Bindheim. ‡ *Jour. de Min.* No. xxxiv. 769.

§ Vauquelin, *Jour. de Min.* No. lv. 523.

CHAP. III.

METHOD OF ANALYSING MINERALS.

Analyses of minerals

THE progress which the art of analysing minerals has made within these last twenty years is truly astonishing. To separate five or six substances intimately combined together, to exhibit each of them separately, to ascertain the precise quantity of each, and even to detect the presence and the weight of substances which do not approach $\frac{1}{500}$th part of the compound, would, at no very remote period, have been considered as a hopeless, if not an impossible, task; yet this can now be done with tolerable accuracy.

Begun by Margraff;

The first person who undertook the analysis of minerals was Margraff of Berlin. His attempts were indeed rude; but their importance was soon perceived by other chemists, particularly by Bergman and Scheele, whose industry and address brought the art of analysing minerals to a considerable degree of perfection.

Improved by Klaproth

But their methods, though they had very considerable merit, and, considering the state of the science, are wonderful proofs of the genius of the inventors, were often tedious and uncertain, and could not in all cases be applied with confidence. These defects were perceived by Mr Klaproth of Berlin, who applied himself to the analysis of minerals with a persevering industry

Book III.

which nothing could fatigue, and an ingenuity and accuracy which nothing could perplex. He corrected what was wrong, and supplied what was wanting, in the analytical method; invented new processes, discovered new instruments; and it is to his labours, more than to those of any other chemist, that the degree of perfection, to which the analysis of minerals has attained, is to be ascribed. Many improvements, however, were introduced by other chemists, especially by Mr Vauquelin, whose analyses, in point of accuracy and ingenuity, rival those of Klaproth himself.

And others.

I shall, in the following Sections, describe the method of analysing minerals at present practised by chemists. But it will be proper, in the first place, to premise the following observations.

Method of reducing a mineral to powder.

Before a mineral is submitted to analysis, it ought to be reduced to an impalpable powder. This is by no means an easy task when the stone is extremely hard. It ought to be raised to a bright red or white heat in a crucible, and then instantly thrown into cold water. This sudden transition makes it crack and break into pieces. If these pieces are not small enough, the operation may be repeated on each till they are reduced to the proper size. These fragments are then to be beaten to small pieces in a polished steel mortar; the cavity of which should be cylindrical, and the steel pestle should fit it exactly, in order to prevent any of the stone from escaping during the act of pounding. As soon as the stone is reduced to pretty small pieces, it ought to be put into a mortar of rock crystal or flint, and reduced to a coarse powder. This mortar should be about four inches in diameter, and rather more than an inch in depth. The pestle should be formed of the same stone with the mortar, and care should be taken to know exactly the ingredients of which this mortar is composed. Klaproth's mortar is of flint.

When the stone has been reduced to a coarse powder, a certain quantity, whose weight is known exactly, 100 grains for instance, ought to be taken and reduced to as fine a powder as possible. This is best done by pounding small quantities of it at once, not exceeding 10 grains. The powder is as fine as possible when it feels soft, adheres together, and as it were forms a cake under the pestle. It ought then to be weighed exactly. It will almost always be found heavier after being pounded than it was before; owing to a certain quantity of the substance of the mortar which has been rubbed off during the grinding, and mixed with the powder. This additional weight must be carefully noted; and after the analysis, a portion of the ingredients of the mortar, corresponding to it, must be subtracted.

Chemical vessels.

It is necessary to have a crucible of pure silver, or, what is far preferable, of platinum, capable of holding rather more than seven cubic inches of water, and provided with a cover of the same metal. There should also be ready a spatula of the same metal about four inches long.

The dishes in which the solutions, evaporations, &c. are performed, ought to be of glass or porcelain. Those of porcelain are cheaper, because they are not so apt to break. Those which Mr Vauquelin uses are of porcelain; they are sections of spheres, and are glazed both within and without, except that part of the bottom which is immediately exposed to the fire.

SECT. I.

ANALYSIS OF EARTHS AND STONES*.

Ingredients of stones.

The only substances which enter into the composition of the simple stones, as far at least as analysis has discovered, are the six earths, silica, alumina, zirconia, glucina, lime, and magnesia; and the oxides of iron, manganese, nickel, chromum, and copper†. Seldom more than four or five of these substances are found combined together in the same stone: we shall suppose, however, in order to prevent unnecessary repetitions, that they are all contained in the mineral which we are going to analyse.

Method of decomposing stones.

Let 100 or 200 grains of the stone to be analysed, previously reduced to a fine powder, be mixed with three times its weight of pure potass and a little water, and exposed in the silver or platinum crucible to a strong heat. The heat should at first be applied slowly, and the matter should be constantly stirred, to prevent the potass from swelling and throwing any part out of the crucible. When the whole water is evaporated, the mixture should be kept for half an hour or three quarters in a strong red heat.

If the matter in the crucible melts completely, and appears as liquid as water, we may be certain that the

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[*] See Vauquelin's Treatise on the Analysis of Stones, *Ann. de Chim.* xxx. 66.

[†] Barytes has also been discovered in one single stone, the *staurolite*; but its presence in stones is so uncommon, that it can scarcely be looked for. The method of detecting it shall be noticed afterwards.

one which we are analysing consists chiefly of silica ;
it remains opaque, and of the consistence of paste, the
her earths are most abundant ; if it remains in the
rm of a powder, alumina is the prevalent earth. If
e matter in the crucible be of a dark or brownish red
lour, it contains oxide of iron ; if it is grass green,
anganese is present ; if it is yellowish green, it con-
ins chromum.

When the crucible has been taken from the fire and
iped on the outside, it is to be placed in a capsule of
rcelain, and filled with water. This water is to be
newed, from time to time, till all the matter is detach-
l from the crucible. The water dissolves a part of the
mbination of the alkali with the silica and alumina
the stone ; and if a sufficient quantity were used, it
ould dissolve the whole of that combination.

Muriatic acid is now to be poured in till the whole
the matter is dissolved. At first a flaky precipitate
pears, because the acid combines with the alkali
hich kept it in solution. Then an effervescence takes
ace, owing to the decomposition of some carbonat of
tass formed during the fusion. At the same time
e flaky precipitate is redissolved ; as is also that part
the matter which, not having been dissolved in the
ater, had remained at the bottom of the dish in the
rm of a powder. This powder, if it consists only of
ica and alumina, dissolves without effervescence; but
it contains lime, an effervescence takes place.

If this solution in muriatic acid be colourless, we may
nclude that it contains no metallic oxide, or only a
ry small portion ; if its colour be purplish red, it con-
ins manganese ; orange red indicates the presence of
on ; and golden yellow the presence of chromum.

This solution is to be poured into a capsule of porcelain, covered with paper, and evaporated to dryness in a sand bath. When the evaporation is drawing towards its completion, the liquor assumes the form of jelly. It must then be stirred constantly with a glass or porcelain rod, in order to facilitate the disengagement of the acid and water, and to prevent one part of the matter from being too much, and another not sufficiently dried. Without this precaution, the silica and alumina would not be completely separated from each other.

How the silica is separated.

When the matter is reduced almost to a dry powder, a large quantity of pure water is to be poured on it; and, after exposure to a slight heat, the whole is to be poured on a filter. The powder which remains upon the filter is to be washed repeatedly, till the water with which it has been washed ceases to precipitate silver from its solutions. This powder is the whole of the *silica* which the stone that we are analysing contained. It must first be dried between folds of blotting paper, then heated red hot in a platinum or silver crucible, and weighed while it is yet warm. It ought to be a fine powder, of a white colour, not adhering to the fingers, and entirely soluble in acids. If it be coloured, it is contaminated with some metallic oxide; and shews that the evaporation to dryness has been performed at too high a temperature. To separate this oxide, the silica must be boiled with an acid, and then washed and dried as before. The acid solution must be added to the water which passed through the filter, and which we shall denominate A.

The watery solution A is to be evaporated till its quantity does not exceed 30 cubic inches, or nearly an English pint. A solution of carbonat of potass is then be poured into it till no more matter precipitates. ought to be boiled a few moments to enable all the ecipitate to fall to the bottom. When the whole of e precipitate has collected at the bottom, the super- tant liquid is to be decanted off; and water being bstituted in its place, the precipitate and water are to thrown upon a filter. When the water has run off, e filter with the precipitate upon it is to be placed tween folds of blotting paper. When the precipi- te has acquired some consistence, it is to be carefully llected by an ivory knife, mixed with a solution of re potass, and boiled in a porcelain capsule. If any umina or glucina be present, they will be dissolved in e potass; while the other substances remain untouch- l in the form of a powder, which we shall call B.

Method of separating the alumina,

Into the solution of potass as much acid must be ured as will not only saturate the potass, but also mpletely redissolve any precipitate which may have first appeared. Carbonat of ammonia is now to be lded in such quantity that the liquid shall taste of it. y this addition the whole of the alumina will be pre- pitated in white fleaks, and the glucina will remain dis- lved, provided the quantity of carbonat of ammonia sed be not too small The liquid is now to be filter- , and the alumina which will remain on the filter is to washed, dried, heated red hot, and then weighed. o see if it be really alumina, dissolve it in sulphuric id, and add a sufficient quantity of sulphat or acetite potass; if it be alumina, the whole of it will be con- rted into crystals of alum.

Glucina,

Let the liquid which has passed through the filter be iled for some time; and the glucina, if it contains any, ill be precipitated in a light powder, which may be dried and weighed. When pure, it is a fine, soft, very light, tasteless powder, which does not concrete when heated, as alumina does.

Lime,

The residuum B may contain lime, magnesia, and one or more metallic oxides *. Let it be dissolved in weak sulphuric acid, and the solution evaporated to dryness. Pour a small quantity of water on it. The water will dissolve the sulphat of magnesia and the metallic sulphats; but the sulphat of lime will remain undissolved. Let it be heated red hot in a crucible, and weighed. The lime amounts to 0.42 of the weight.

Let the solution containing the remaining sulphats be diluted with a large quantity of water, let a small excess of acid be added, and then let a saturated carbonat of potass be poured in. The oxides of chromum, iron, and nickel, will be precipitated, and the magnesia and oxide of manganese will remain dissolved. The precipitate we shall call C.

Manganese,

Magnesia,

Into the solution let a solution of hydrosulphuret of potass be poured, and the manganese will be precipitated in the state of a hydrosulphuret. Let it be calcined in contact with air, and weighed. The magnesia may then be precipitated by pure potass, washed, exposed to a red heat, and then weighed.

Chromum,

Let the residuum C be boiled repeatedly with nitric acid, then mixed with pure potass; and after being heated, let the liquid be decanted off. Let the precipitate, which consists of the oxides of iron and nickel, be washed with pure water; and let this water be added to the solution of the nitric acid and potass. That so-

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* If yttria be suspected, let the residuum B be treated with carbonat of ammonia, which will dissolve the yttria and leave the other bodies. Then proceed as above.

tion contains the chromum converted into an acid. dd to this solution an excess of muriatic acid, and aporate till the liquid assumes a green colour; then d a pure alkali: The chromum precipitates in the ite of an oxide, and may be dried and weighed.

Iron,

Let the precipitate, consisting of the oxides of iron d nickel, be dissolved in muriatic acid; add an ex- ss of ammonia: the oxide of iron precipitates. Let it washed, dried, and weighed.

Nickel.

Evaporate the solution, and the oxide of nickel will so precipitate; and its weight may be ascertained in e same manner with the other ingredients.

The weights of all the ingredients obtained are now be added together, and their sum total compared with e weight of the matter submitted to analysis. If the o are equal, or if they differ only by .03 or .04 parts, may conclude that the analysis has been properly formed; but if the loss of weight be considerable, mething or other has been lost. The analysis must erefore be repeated with all possible care. If there still the same loss of weight, we may conclude that e stone contains some substance, which has either eva- rated by the heat, or is soluble in water.

Method of detecting volatile bodies,

A fresh portion of the stone must therefore be bro- en into small pieces, and exposed in a porcelain cru- ble to a strong heat. If it contains water, or any her volatile substance, they will come over into the ceiver; and their nature and weight may be ascer- ined.

If nothing comes over into the receiver, or if what mes over is not equal to the weight wanting, we may nclude that the stone contains some ingredient which soluble in water.

And of discovering whether potass be present,

To discover whether it contains *potass*, let the stone, reduced to an impalpable powder, be boiled five or six times in succession, with very strong sulphuric acid, applying a pretty strong heat towards the end of the operation, in order to expel the excess of acid; but taking care that it be not strong enough to decompose the salts which have been formed.

Water is now to be poured on, and the residuum, which does not dissolve, is to be washed with water till it becomes tasteless. The watery solution is to be filtered, and evaporated to dryness, in order to drive off any excess of acid which may be present. The salts are to be again dissolved in water; and the solution, after being boiled for a few moments, is to be filtered and evaporated to a consistence proper for crystallizing. If the stone contains a sufficient quantity of alumina, and if potass be present, crystals of alum will be formed: and the quantity of potass may be discovered by weighing them, it being nearly $\frac{1}{10}$th of their weight. If the stone does not contain alumina, or not in sufficient quantity, a solution of pure alumina in sulphuric acid must be added. Sometimes the alum, even when potass is present, does not appear for several days or even weeks; and sometimes, when a great quantity of alumina is present, if the solution has been too much concentrated by evaporation, the sulphat of alumina prevents the alum from crystallizing at all. Care, therefore, must be taken to prevent this last source of error. The alum obtained may be dissolved in water, and barytic water poured into it as long as any precipitate forms. The liquor is to be filtered, and evaporated to dryness. The residuum will consist of potass and a little carbonat of potass. The potass may be dissolved in a little water, This solution, evaporated to dryness, gives us the potass pure; which may be examined and weighed.

Or soda.

If no crystals of alum can be obtained, we must look for some other substance than potass. The stone, for instance, may contain soda. The presence of this alkali may be discovered by decomposing the solution in sulphuric acid, already described, by means of ammonia. The liquid which remains is to be evaporated to dryness, and the residuum is to be calcined in a crucible. By this method, the sulphat of ammonia will be volatilized, and the soda will remain. It may be redissolved in water, crystallized, and examined.

If sulphuric acid does not attack the stone, as is often the case, it must be decomposed by fusion with soda, in the same manner as formerly directed with potass. The matter, after fusion, is to be diluted with water, and then saturated with sulphuric acid. The solution is to be evaporated to dryness, the residuum again dissolved in water, and evaporated. Sulphat of soda will crystallize first; and by a second evaporation, if the stone contains potass and alumina, crystals of alum will be deposited.

The presence of potass may be discovered, by mixing with a somewhat concentrated solution of muriat of platinum the salt obtained, either by decomposing the stone immediately by an acid, or by saturating with an acid the matter obtained by fusing the stone with soda. If any potass be present, a very red precipitate will be formed. This precipitate is a triple salt, composed of potass, muriatic acid, and oxide of platinum. Ammonia, indeed, produces the same precipitate; but ammonia has not hitherto been discovered in stones.

Analysis of saline stones,

In this manner may simple stones and aggregates be

Book III. analysed. As to saline stones, their analysis must vary according to the acid which they contain. But almost all of them may be decomposed by one or other of two methods; of each of which I shall give an example.

I. Analysis of Carbonat of Strontian.

Of carbonats, Klaproth analysed this mineral by dissolving 100 parts of it in diluted muriatic acid: during the solution 30 parts of carbonic acid escaped. The solution crystallized in needles, and when dissolved in alcohol, burnt with a purple flame. Therefore it contained strontian. He dissolved a grain of sulphat of potass in six ounces of water, and let fall into it three drops of the muriatic solution. No precipitate appeared till next day. Therefore the solution contained no barytes; for if it had, a precipitate would have appeared immediately.

He then decomposed the muriatic acid solution, by mixing it with carbonat of potass. Carbonat of strontian precipitated. By the application of a strong heat, the carbonic acid was driven off. The whole of the earth which remained was dissolved in water. It crystallized; and, when dried, weighed 69½*.

II. Analysis of Sulphat of Strontian.

Sulphats, Vauquelin analysed an impure specimen of this mineral as follows:

On 200 parts of the mineral, diluted nitric acid was poured. A violent effervescence took place, and part of the mineral was dissolved. The undissolved portion, after being heated red hot, weighed 167. Therefore 33 parts were dissolved.

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* Klaproth's Beitrage, i. 260.

The nitric solution was evaporated to dryness: A reddish substance remained, which indicated the presence of oxide of iron. This substance was redissolved in water, and some ammonia mixed with it; a reddish precipitate appeared, which, when dried, weighed 1, and was oxide of iron. The remainder of the solution was precipitated by carbonat of potass. The precipitate weighed, when dried, 20, and possessed the properties of carbonat of lime. Therefore 200 parts of this mineral contain 20 of carbonat of lime, 1 of oxide of iron, and the remainder of the 33 parts he concluded to be water.

The 167 parts, which were insoluble in nitric acid, were mixed with 500 parts of carbonat of potass, and 7000 parts of water, and boiled for a considerable time. The solution was then filtered, and the residuum washed and dried. The liquid scarcely effervesced with acids; but with barytes it produced a copious precipitate, totally indissoluble in muriatic acid. Therefore it contained sulphuric acid.

The undissolved residuum, when dried, weighed 129 parts. It dissolved completely in muriatic acid. The solution crystallized in needles; when dissolved in alcohol, it burnt with a purple flame: and, in short, had all the properties of muriat of strontian. Therefore these 129 parts were carbonat of strontian. Now, 100 parts of this carbonat contain 30 of carbonic acid; therefore 129 contain 38.7. Therefore the mineral must contain in 200 parts 90.3 of strontian.

Now, the insoluble residuum of 167 parts was pure sulphat of strontian; and we have seen that it contain-

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* *Jour. de Min.* No. xxxvii. 1.

ed 90.3 of strontian. Therefore the sulphuric acid must amount to 76.7 parts*.

Nearly in the same manner as in the first of these examples may the analysis of carbonat of lime and barytes be prformed; and nearly in the same manner with the second we may analyse the sulphats of lime and barytes.

Phosphats,

Phosphat of lime may be dissolved in muriatic acid, and the lime precipitated by sulphuric acid, and its quantity ascertained by decomposing the sulphat of lime obtained. The liquid solution may be evaporated to the consistence of honey, mixed with charcoal powder, and distilled in a strong heat By this means phosphorus will be obtained The impurities with which the phosphat may be contaminated will partly remain undissolved, and be partly dissolved, in muriatic acid. They may be detected and ascertained by the rules laid down in the First Section of this Chapter.

Fluats,

The fluat of lime may be mixed with sulphuric acid and distilled. The fluoric acid will come over in the form of gas, and its weight may be ascertained. What remains in the retort, which will consist chiefly of sulphat of lime, may be analysed by the rules already laid down.

Borats.

The borat of lime may be dissolved in nitric or sulphuric acid: The solution may be evaporated to dryness, and the boracic acid separated from the residuum by means of alcohol, which will dissolve it without acting on any of the other ingredients. The remainder of the dry mass may be analysed by the rules laid down in this Section.

SECT. II.

OF THE ANALYSIS OF COMBUSTIBLES.

THE only combustibles of whose analysis it will be necessary to speak are coals and sulphur; for the method of analysing the diamond and oil has already been given in the First Part of this Work.

Method of analysing coal.

Coal is composed of charcoal, bitumen, and some portion of earth. The earths may be detected by burning completely a portion of the coal to be analysed. The ashes which remain after incineration consist of the earthy part. Their nature may be ascertained by the rules laid down in Sect. I. of this Chapter.

For the method of ascertaining the proportion of charcoal and bitumen in coal, we are indebted to Mr Kirwan.

When nitre is heated red hot, and charcoal is thrown on it, a violent detonation takes place; and if the quantity of charcoal be sufficient, the nitre is completely decomposed. Now, it requires a certain quantity of pure charcoal to decompose a given weight of nitre. From the experiments of Lavoisier, it follows, that when the detonation is performed in close vessels under water, 13.21 parts of charcoal are capable of decomposing 100 parts of nitre[*]. But when the detonation is performed in an open crucible, a smaller proportion of charcoal is necessary, because part of the nitre is decomposed by

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[*] *Mem. Scav. Etrang.* xi. 626.

Book III. the action of the surrounding air. Scheele found, that under these circumstances 10 parts of plumbago were sufficient to decompose 96 parts of nitre, and Mr Kirwan found, that nearly the same quantity of charcoal was sufficient for producing the same effect.

Macquer long ago observed that no volatile oily matter will detonate with nitre, unless it be previously reduced to a charcoal; and that then its effect upon nitre is precisely proportional to the charcoal which it contains[*]. Mr Kirwan, upon trying the experiment with *vegetable pitch* and *maltha*, found that these substances did not detonate with nitre, but merely burn upon its surface with a white or yellow flame; and that after they were consumed, nearly the same quantity of charcoal was necessary to decompose the nitre which would have been required if no bitumen had been used at all[†]. Now coals are chiefly composed of charcoal and bitumen. It occurred therefore to Mr Kirwan, that the quantity of charcoal which any coal contains may be ascertained by detonating it with nitre: For since the bitumen of the coal has no effect in decomposing nitre, it is evident that the detonation and decomposition must be owing to the charcoal of the coal; and that therefore the quantity of coal necessary to decompose a given portion of nitre will indicate the quantity of carbon which it contains: and the proportion of charcoal and earth which any coal contains being ascertained, its bituminous part may be easily had from calculation.

The crucible which he used in his experiments was large; it was placed in a wind furnace at a distance

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[*] Macquer's *Dictionary*, Second Edit. p. 481.

[†] *Miner.* ii. 522.

from the flue, and the heat in every experiment was as equal as possible. The moment the nitre was red hot, the coal, previously reduced to small pieces of the size of a pin head, was projected in portions of one or two grains at a time, till the nitre would no longer detonate; and every experiment was repeated several times to ensure accuracy.

He found, that 480 grains of nitre required 50 grains of Kilkenny coal to decompose it by this method. Therefore 10 grains would have decomposed 96 of nitre; precisely the quantity of charcoal which would have produced the same effect. Therefore Kilkenny coal is composed almost entirely of charcoal.

Cannel coal, when incinerated, left a residuum of 3.12 in the 100 parts of earthy ashes. 66.5 grains of it were required to decompose 480 grains of nitre; but 50 parts of charcoal would have been sufficient: therefore 66.5 grains of cannel coal contain 50 grains of charcoal, and 2.08 of earth; the remaining 14 42 grains must be bitumen. In this manner may the composition of any other coal be ascertained.

Method of analysing sulphur.

As for sulphur, in order to ascertain any accidental impurities with which it may be contaminated, it ought to be boiled in thirty times its weight of water, afterwards in diluted muriatic acid, and lastly treated with nitro-muriatic acid. These substances will deprive it of all its impurities without acting on the sulphur itself, at least if the proper cautions be attended to. The sulphur may then be dried and weighed. The deficiency in weight will mark the quantity of the substances which contaminate the sulphur. The solutions may be evaporated and examined, according to the rules laid down in the First and Third Sections of this Chapter.

SECT. III.

ANALYSIS OF ORES.

No general method.

THE diversity of metallic ores is so great, that no general method of analysis can be given. Let us therefore follow the different orders, one by one, and point out the proper method of analysing each. In the rules which I propose to give, I shall follow Bergman, to whom we are indebted for the first precise treatise on the analysis of ores, except when his methods have been superseded by the improvements of succeeding chemists.

I. Gold Ores.

The presence of gold may easily be detected by treating the mineral supposed to contain it with nitro-muriatic acid, and dropping muriat of tin into the solution. If the solution contains any gold a purple precipitate immediately appears.

Analysis of native gold.

Native gold ought to be dissolved in nitro-muriatic acid: the silver, if any be present, falls to the bottom in the state of muriat, and may be separated by filtration, and weighed. Pour sulphat of iron into the solution, and the gold is precipitated in the metallic state. The copper, if any be present, may be precipitated by means of a plate of iron. The presence of iron may be ascertained by dropping tincture of nutgalls into a portion of the solution *.

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* Bergman, ii. 410.

The auriferous pyrites may be treated with diluted itrous acid, which dissolves the iron and separates the ulphur. The gold remains insoluble, and is found in he state of small grains.

II. Ores of Platinum.

Proust's method of analysing platina.

The most complete treatise on the analysis of the re of this metal which has hitherto appeared is that of Proust. But even the experiments of this ingenious hemist are not sufficient to make us thoroughly acquainted with this complicated ore. No accurate method of analysis then can be expected. Proust first eparates the sand with which the grains of platina are mixed, by exposing them to a blast of air. By heat he evaporates the mercury, which still adheres to them *, and then picks out the grains of gold, which are thus rendered visible. The ore is then dissolved in an acid composed of 1 part of nitre and 3 parts of muriatic acid. A black powder remains. This powder, when roasted, gives out phosphorus and sulphur. After this it is dissolved by nitro-muriatic acid, except a small residuum, which is plumbago. The solutions are then to be mixed. They consist of muriats of platinum, and oxy-muriats of copper and iron. By evaporating till the liquid when cold assumes a consistency greater than honey, and inclining the retort, the oxy-muriats run off, and leave the muriat of platinum, which may be obtained pure by repeated solutions and crystallizations. The solution containing the muriats, and per-

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* Platina is found always mixed with grains of gold. The Spanish miners separate the gold by amalgamation; but part of the gold usually remains in the state of an amalgam.

haps also a little platinum, is to be diluted with a great proportion of water, and pure ammonia dropt in. The red oxide of iron precipitates, and may be estimated by weighing it. When the solution is somewhat concentrated, ammonia precipitates the platinum in the state of a triple salt; and the copper, which now only remains, may be precipitated by a plate of iron [*].

III. Ores of Silver.

The analysis of the ores of silver has been always considered as very important, on account of the great value of the metal which they contain in greatest abundance.

Analysis of native silver.

1. Native silver is to be dissolved in nitric acid. The gold, if the ore contains any, remains in the state of a black powder, and may be dried and weighed. The silver may be precipitated by common salt. One hundred parts of the precipitate dried, denote about 75 parts of silver. The presence of copper may be ascertained by the green colour of the solution, and by the blue colour which it assumes on adding ammonia. The copper may be precipitated by a plate of iron, or by the rules laid down hereafter. When the ore contains arsenic, its proportion may be estimated by weighing before and after fusion; for the arsenic is dissipated by heat, or the ore may be dissolved as before in nitric acid, which acidifies the arsenic. After the separation of the silver, the arsenic acid may be precipitated by nitrat of lead, 100 parts of the dry precipitate indicating about 22 of arsenic.

2. Alloy of silver and antimony is to be treated

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[*] *Ann. de Chim.* xxxviii. 146.

ith nitric acid, which dissolves the silver and oxidates ıe antimony. The silver is estimated as above. The ‹ide of antimony may be reduced by fusion with ›ur times its weight of black flux and a little soap *.

Sulphuret of silver.

3. Sulphuret of silver is to be treated with diluted tric acid, which dissolves the silver, leaving the 'eater part of the sulphur untouched. The residuum to be dried, and then the sulphur burnt off. The ss of weight gives the sulphur. The residuum, if any, the gangue of the ore, which may be analysed by the ıles laid down in the First Section of this Chapter. he silver is to be precipitated by common salt; and .e other metals, if any be present, may be ascertained ; above. Part of the sulphur is always acidified The :id thus formed may be precipitated by nitrat of barites, 100 parts of the dried precipitate indicating ›out 14.5 of sulphur.

Antimoniated silver ore.

4. Antimoniated silver ore was analysed by Klaproth the following manner: 100 parts of it were boiled ı diluted nitric acid. The residuum, washed and dried, as 26. These 26 were digested in nitro-muriatic :id. The residuum now weighed 13 (so that 13 had :en dissolved), 12 of which were sulphur, and burnt ıvay, leaving behind them one part of silica. The 'tro-muriatic solution, when diluted largely with water, :t fall a precipitate which weighed 13 (or 10 of pure ıtimony), and had the properties of oxide of antimony; r they did not evaporate till heated to redness, but at at temperature were dissipated in a grey smoke.

The nitric solution was green. Common salt occa-ɔned a precipitate which weighed 87.75, equivalent

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* Selb. Kirwan's *Min.* ii. 346.

to 65.81 of pure silver. After the separation of this muriat of silver, sulphat of soda occasioned no precipitate. Therefore the solution contained no lead. When supersaturated with soda, a grey precipitate fell weighing 5 parts. On burning coals this precipitate gave out an arsenical smell. It was redissolved in nitric acid; sulphurated alkali occasioned a smutty brown precipitate; and prussic alkali a prussian blue, which, after torrefaction, was magnetic. Hence he concluded, that these 5 parts were a combination of iron and arsenic acid.

The nitric solution which had been supersaturated with ammonia was blue; he therefore suspected that it contained copper. To discover this, he saturated it with sulphuric acid, and put into it a polished plate of iron. The quantity of copper was so small, that none could be collected on the iron *.

Sulphuret.

5. Sulphuret of silver and copper may be analysed as No. 3. separating the copper by means of a plate of iron.

Calciform ore.

6. Calciform silver ore may be analysed as No. 2. separating the copper, if any be present, by means of an iron plate, and estimating the carbonic acid that escapes when the ore is heated or dissolved in nitric acid.

Red silver ore.

7. Red silver ore was analysed by Vauquelin in the following manner: One hundred parts of it were digested in 500 parts of nitric acid previously diluted with water †. The undissolved residuum, being washed and dried, weighed 42.06. Being treated with muriatic acid,

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* Klaproth's Beitrage, i. 63.

† No effervescence occurred during the solution; a proof that the metals existed in the ore in the state of oxides.

was all dissolved except 14.66 parts, which were sul-
ur. The muriatic solution, when diluted with a great
antity of water, deposited a white powder, which
eighed 21.25, and was oxide of antimony. The ni-
c acid solution remained still to be examined. Mu-
tic acid occasioned a heavy precipitate, which weigh-
72.66 parts, and which was muriat of silver. Re-
ents shewed that the acid retained no other substance
solution *.

Muriat of silver.

8. Muriat of silver was analysed by Klaproth in the
llowing manner: One hundred parts of it were mix-
with thrice their weight of pure carbonat of potass,
d melted together in a glass retort. The mass was
ssolved in water, and the solution filtered. A resi-
um remained, which was dissolved in nitric acid,
ith the exception of a red powder; which, treated
ith nitro-muriatic acid, was dissolved, except a little
uriat of silver, which, when reduced, yielded .5 of
re silver. Ammonia precipitated from the nitro-mu-
atic solution 2.5 parts of oxide of iron. The nitric
lution was precipitated by common salt; the muriat
silver, thus obtained, yielded, when reduced, 67.25
pure silver.

The original aqueous solution of the alkaline mass
as saturated with acetous acid, on which it deposited
75 parts of alumina. The solution was evaporated to
yness, and the dry mass treated with alcohol, which
ssolved the acetite of potass. The residuum, amount-
g to 58.75 parts, was dissolved in water; and being
eated with muriat of barytes, 15 parts of sulphat of
arytes precipitated, indicating the presence of about

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* *Jour. de Min.* No. xvii. p. 2.

.5 of sulphuric acid, or 0.75 sulphat of potass. The remaining 58 parts were muriat of potass, indicating about 21 parts of muriatic acid *.

IV. Ores of Mercury.

We have very few exact analyses of the ores of mercury, owing, perhaps, to the facility with which the mercury is extracted from them by distillation.

Native mercury and amalgam.

1. Native mercury and amalgam may be dissolved in nitric acid. The gold, if any be present, remains in the state of powder, and may be estimated by its weight. The affusion of water precipitates the bismuth, if the solution happens to contain any. Common salt precipitates the silver, and also part of the mercury; but the latter may be redissolved by a sufficient quantity of water, or, which is far better, of oxy-muriatic acid, while the muriat of silver remains insoluble. Lastly, the mercury may be precipitated by sulphat of iron, and estimated †.

Cinnabar.

2. Native cinnabar may be treated with a mixture of three parts muriatic and one part nitric acid, which dissolves the mercury, and leaves the sulphur. The mercury may be estimated as in the last paragraph ‡.

3. Hepatic mercurial ore has not been analysed. Its analysis may be attempted as in No. 2. or by dissolving it in nitric acid.

Muriat of mercury.

4. Muriat of mercury may be digested in muriatic acid till the whole is dissolved. Muriat of barytes precipitates the sulphuric acid, 100 parts of which are equivalent to 186 of sulphat of mercury; and the propor-

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* Klaproth's Beitrage. i. 132.

† Bergman, ii. 421.

‡ Hildebrandt, Kirwan's *Mineral.* ii. 420.

n of this salt being known, we have that of the mu-
t [*].

V. Ores of Copper.

Native copper.

1. Native copper sometimes contains gold, silver, or n. It may be dissolved in nitric acid; the gold re- ins in the state of a blackish or rather violet colour- powder; the silver may be separated by a polished ate of copper (or it may be precipitated from a sepa- te portion of the solution by common salt); the iron ay be separated by boiling the solution to dryness, and eating the residuum with water. By this process, the trat of iron is decomposed; the oxide of iron remains, hile the water dissolves the nitrat of copper [†]. This st salt may be decomposed by boiling it with potass: e precipitate, dried in a red heat, is black oxide of pper. One hundred parts of it denote 80 of metallic pper [‡].

Sulphuret of copper.

2. Sulphuret of copper may be dissolved in diluted tric acid. Part of the sulphur remains unaltered, and ay be estimated by weighing it, and burning it off. art is acidified, and may be precipitated by nitrat of rytes; 100 parts of the dried precipitate indicating .5 of sulphur. By evaporation to dryness, and solu- on in water, the iron is separated; and the copper may estimated as in the last paragraph; or muriatic acid ay be used instead of nitric: but in that case it is ore difficult to obtain a complete solution.

Grey copper ore.

3. Grey copper ore was analysed by Klaproth in the llowing manner: Three hundred parts of it were di-

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[*] Bergman, ii. 423.

[†] Ibid, p. 427.

[‡] Chenevix, *Phil. Trans.* 1801, p. 209.

gested with four times their weight of nitric acid. This operation was repeated, and the two acid liquids mixed. The undissolved residuum was 188 parts. The nitric solution was green, and, when common salt was added to it, muriat of silver precipitated. The solution being now supersaturated with ammonia, 9.5 parts of a flaky red precipitate were obtained; which was found to be composed of silica, alumina, and iron, by dissolving it in muriatic acid, and proceeding by the rules laid down in the First Section of this Chapter. A polished iron plate precipitated from the nitric solution 69 parts of copper.

The 188 parts of residuum were boiled with six times their weight of muriatic acid; 105.5 parts remained undissolved, which were sulphur and silica. The muriatic acid solution being concentrated, yielded a little muriat of silver. Being diluted with a large portion of water, a white powder precipitated, which weighed 97.5 parts, and was oxide of antimony.

Red copper ore.

4. Red copper ore has only to be dissolved in muriatic acid, and the copper precipitated by a plate of iron; 88 parts of the precipitated copper being equivalent to 100 of the orange oxide of which the ore is composed.

Oxides.

5. The analysis of the oxides and carbonats of copper scarcely requires any remarks. The water and carbonic acid must be estimated by distillation in close vessels, and collecting the products. The ore may then be dissolved in nitric acid, and its copper ascertained as above.

Arseniat.

6. Arseniat of copper was analysed by Mr Chenevix, in the following manner: The ore was dissolved in diluted nitric acid, and nitrat of lead poured in. The solution was evaporated till a precipitate began to appear,

and then mixed with alcohol. Arseniat of lead precipitated. One hundred parts of this salt indicate 33 of arsenic acid. The copper was separated from the nitric acid by boiling it with potass *.

VI. Ores of Iron.

Notwithstanding the great variety of iron ores, they may be all, as far as analysis is concerned, arranged under three heads; namely, 1. Sulphurets; 2. Oxides; and, 3. Salts.

Pyrites

1. Pyrites, or sulphurated iron, may be treated repeatedly with boiling nitric acid till the sulphur is acidified. Muriatic acid is then to be added, and the digestion continued till the whole be dissolved †. Muriat of barytes is then to be added to precipitate the sulphuric acid; 100 of the dried precipitate indicates 14.5 of sulphur. If the solution contains only iron, it may be precipitated by carbonat of soda, calcined to redness, and weighed. But if earths or manganese be present, we must proceed by the rules laid down in the First Section of this Chapter.

Oxides.

2. If the oxides of iron be pure, that is to say, contain nothing but iron, we have only to dissolve them in muriatic acid, and precipitate them as above. But it is very seldom that ores possess this perfect degree of purity. The iron is usually combined with manganese, alumina, silica, or with all of these together. The analysis is to be conducted exactly according to the rules laid down in the First Section of this Chapter.

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[*] *Phil. Trans.* 1801, p. 195.

[†] If any siliceous gangue be mixed with the ore, of course it will remain undissolved, and must be analysed according to the rules laid down in the First Section of this Chapter.

Book III.

Sparry iron ore.

3. The sparry iron ore may be analysed in the same manner, excepting only that the carbonic acid gas must be separated by distillation or solution in close vessels, and estimated by the rules laid down in the Fourth Chapter of the last Book *.

Arseniat.

4. Arseniat of iron was analysed by Mr Chenevix in the following manner: One hundred parts of it were boiled with potass till the arsenic acid was separated. Nitrat of lead was mixed with the solution; 100 parts of the precipitate indicated 33 of arsenic acid. That portion of the ore which eluded the action of the potass was treated with muriatic acid; the undissolved residuum was silica. The muriatic acid was supersaturated with ammonia. The iron precipitated; but the copper was dissolved by the ammonia †.

VII. Ores of Tin.

For the method of analysing the ores of tin we are indebted solely to Klaproth; the mode of analysis indicated by Bergman does not succeed.

Sulphuret of tin.

1. The sulphuret of tin was thus analysed by Klaproth: 120 parts of the ore was digested with nitro-muriatic acid. 43 parts remained undissolved. Of these, 30 burnt away with a blue flame, and were sulphur; of the remaining 13, 8 dissolved in nitro-muriatic acid. The undissolved 5 were heated with wax, and yielded a grain of iron attracted by the magnet. The rest was a mixture of alumina and silica. The nitro-muriatic solution was completely precipitated by potass, and the precipitate redissolved in muriatic acid. A cylinder of tin

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* See Vol. III. p. 403.

† *Phil. Trans.* 1801, p. 219.

recipitated 44 parts * of copper from this solution, nd lost itself 89 parts of its weight. A cylinder of inc precipitated 130 parts of tin; so that, deducting he 89 parts of tin dissolved during the precipitation of he copper, 41 remain for the tin contained in the ore †.

Tinstone.

2. Tinstone was thus analysed by the same celebraed chemist. One hundred parts of the ore were heated o redness, with 600 parts of potass, in a silver crucible; nd the mixture being treated with warm water, 11 arts remained undissolved. These 11, by a repetition of the treatment with potass, were reduced to 1$\frac{1}{4}$th. This small residuum dissolved in muriatic acid. Zinc precipitated from the solution one-half part of tin, and the prussian alkali gave a blue precipitate, which indicated one-fourth part of iron.

The alkaline solution was saturated with muriatic acid; a white precipitate appeared, but it was redissolved by adding more acid. The whole was precipitated by carbonat of soda. The solution, which had a yellowish colour, was redissolved in muriatic acid; and a cylinder of zinc being inserted into the solution, 77 of tin were obtained, indicating nearly 98 parts of oxide of tin ‡.

VIII. Ores of Lead.

Sulphuret.

1. Sulphuret of lead usually contains a little silver, and sometimes also antimony and zinc. It may be treated with diluted nitric acid, which leaves only the sulphur undissolved, the weight of which is to be taken, and its purity determined by combustion. If antimony

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[*] One part of this was found to be tin, by digesting it in nitric acid.

[†] *Observations on the Fossils of Cornwall*, p. 38, English Translation.

[‡] Beitrage, ii. 254.

be present, it will either remain in the state of a white oxide, or, if dissolved, it will be precipitated by diluting the solution with water. Muriatic acid is to be added, and the solution evaporated till it is reduced to a small portion. Muriat of lead and of silver precipitate. The first of these may be dissolved in boiling water, the second remains insoluble. Westrum separated the muriat of silver by digesting the precipitate with ammonia. The liquid from which the muriats were separated may contain iron, zinc, copper. The iron may be precipitated by ammonia added in excess; the copper, by a plate of zinc: the zinc may be precipitated by carbonat of soda reduced to the metallic state, and weighed; subtracting what had been separated from the plate of zinc.

Plumbiferous antimoniated silver ore.

2. Plumbiferous antimoniated silver ore was thus analysed by Klaproth: It was digested with seven times its weight of nitric acid, by which part was dissolved. The residuum was treated repeatedly with muriatic acid, which was poured off while boiling hot. What remained undissolved was sulphur mixed with a little silica. Common salt was added to the nitric solution: two precipitates appeared, 1. A heavy fleaky one, which was muriat of silver; 2. Acicular crystals of muriat of lead. These crystals were dissolved in water, and the solution added to the nitric solution. From this solution sulphat of soda precipitated a heavy white powder, which was sulphat of lead. Lastly, ammonia afforded a precipitate, which was a mixture of iron and alumina. The muriatic solution being concentrated, crystals of muriat of lead appeared; the concentration was continued as long as any crystals formed. The residuum being diluted with water, gave a white precipitate, which was oxide of antimony.

3. The bismuthic silver ore was analysed by Klaroth nearly in the same manner.

Carbonat.

4. Carbonat of lead may be dissolved in nitric acid, ollecting and estimating the carbonic acid. By boiling ne solution, the iron and antimony (if any be present) vill be separated, and may be estimated by solution in uriatic acid; precipitating the antimony by water, nd the iron by ammonia. From the nitric solution the lead may be precipitated by sulphuric acid, and the arth may be examined by the rules laid down in the irst Section of this Chapter.

Phosphat.

5. Phosphat of lead may be dissolved in boiling muiatic acid. The solution is to be diluted with water till he crystals of muriat of lead are dissolved: being then aturated with ammonia, the lead and iron are precipiated. Dissolve the precipitate in muriatic acid, evaporate to dryness, and treat the dry mass with alcohol. The muriat of iron is dissolved; but the muriat of ead remains. Finally, drop lime water into the ammoniacal solution as long as any precipitate appears. That precipitate indicates the proportion of phosphoric acid.

Arseniat.

6. Arseniat of lead has not been analysed. It might be treated with an alkali, which would separate the lead. This metallic precipitate is then to be redissolved in nitric acid, and analysed by the methods above described. The alkaline arseniat may be dissolved in water, and treated with nitrat of lead; 100 parts of the dry precipitate indicate 33 of lead.

Molybdat.

7. Molybdat of lead was thus analysed by Mr Hatchet. The ore was boiled repeatedly with sulphuric acid till the acid refused to dissolve any more. The solution contained the malybdic acid. The undissolved powder

(sulphat of lead) was boiled for an hour with carbona of soda, and then washed. Nitric acid now dissolved it, except a little silica. The lead was precipitated from this solution by sulphuric acid; after which ammonia separated a little oxide of iron. The sulphuric acid solution was diluted with 16 parts of water, and saturated with ammonia; a little oxide of iron gradually precipitated. The solution was now evaporated to dryness, and the mass strongly heated to separate the sulphat of ammonia. The residuum repeatedly treated with nitric acid was converted into yellow molybdic acid.

IX. Ores of Nickel.

No exact method of analysing the ores of nickel has as yet been published.

Kupfer nickel.

1. Kupfer nickel may be dissolved in nitric acid, by which the greatest part of the sulphur will be separated. The arsenic may be afterwards precipitated by the affusion of water. A plate of iron will expel the copper, if any be present. Precipitate by potass added in excess, and boil the precipitate, which will separate the arsenic and sulphur completely. Dissolve the precipitate (previously exposed moist for some time to the air) in acetous acid, and add an excess of ammonia. The iron is precipitated; but the cobalt and nickel remain in solution. Evaporate, and the cobalt is deposited; then by continuing the evaporation to dryness the nickel is obtained.

Arseniat.

2. The arseniat of nickel may be boiled with potass, which separates the acid; the residuum may be analysed as in the last paragraph.

X. Ores of Zinc.

Blende.

1. Blende may be treated with diluted nitric acid,

which will separate the sulphur, the siliceous gangue, &c. The purity of the sulphur is to be ascertained by combustion, and the residuum analysed in the manner formerly described. Precipitate the nitric solution by soda, redissolve in muriatic acid, precipitate the copper (if any be present) by a plate of iron; separate the iron by adding an excess of ammonia*. The zinc now only remains in the solution; which may be obtained by evaporating to dryness, redissolving in muriatic acid, and precipitating by soda.

Calamine.

2. Calamine may be digested in nitric acid, and the insoluble residuum boiled with muriatic acid repeatedly; what remains after dilution with boiling water is silica. The nitric solution contains zinc, and probably also iron and alumina: evaporate to dryness, redissolve, and add an excess of ammonia. The iron and alumina either remain undissolved or are precipitated, and they may be separated by potass. The zinc may be precipitated by an acid, or by evaporation to dryness. The muriatic solution probably contains iron and alumina, which may be precipitated by the rules already laid down.

XI. Ores of Antimony.

Native antimony.

1. Native antimony may be treated with nitric acid, which will oxidate the antimony, and partly dissolve the arsenic. This last metal may be precipitated by concentration and the affusion of water. What remains with the antimony may be dissolved by digestion in boiling water.

Sulphuret.

2. Sulphuret of antimony is to be treated with nitro-

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* Boil this precipitate in potass, to separate the alumina.

muriatic acid. The sulphur and the muriat of silve (if any silver be present) will remain. Water precipitates the antimony; sulphuric acid, the lead; an ammonia, the iron.

XII. Ores of Bismuth.

Native bismuth may be treated with nitric acid Repeated concentrations and affusions of water precipitate the bismuth, and perhaps the arsenic; but this las may be redissolved in boiling water. The cobalt remains, and may be examined by the rules to be hereafter laid down. The same analysis succeeds with the other ores of cobalt. The sulphur when present remains undissolved.

XIII. Ores of Tellurium.

White gold ore.

Klaproth dissolved the white gold ore of Fatzbay in nitro-muriatic acid, and added potass in excess to the solution. A brown precipitate remained undissolved, which was a mixture of gold and iron. It was redissolved in nitro-muriatic acid, the gold first precipitated by nitrat of mercury, and then the iron by potass. The potass in the first solution being saturated with muriatic acid, the oxide of tellurium precipitated*.

The other ores may be analysed in the same manner, only the precipitate occasioned by the potass must be treated according to the metals of which it consists. The rules have been already laid down.

XIV. Ores of Arsenic.

Native arsenic.

1. Native arsenic may be treated with nitro-muriatic

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* Crell's *Annals*, 1798. i. 95.

acid. The silver and gold remain; the first in the state of a muriat; the second may be dissolved by means of nitro-muriatic acid, and precipitated by sulphat of iron. The arsenic may be precipitated by concentrating the nitric solution, and then diluting with water. The iron may then be precipitated by ammonia.

Sulphurets.

2. The sulphurated ores of arsenic may likewise be treated with diluted nitro-muriatic acid. The sulphur remains undissolved; the arsenic may be precipitated by concentration and the affusion of water; the iron by ammonia.

Oxide.

3. Oxide of arsenic may be dissolved in sixteen parts of water. The solution displays acid properties, and nitrat of silver and of mercury occasion precipitates in it.

XV. Ores of Cobalt.

White cobalt ore.

1. White cobalt ore was thus analysed by Tassaert. To ascertain the proportion of arsenic he treated the ore with diluted nitric acid, and obtained a complete solution. Crystals of white oxide of arsenic were deposited, and by repeated evaporations he separated the whole of the arsenic, and ascertained its weight. He then boiled a new portion of the ore with four times its weight of nitric acid, and thus acidified the arsenic, and obtained a solution. This solution was treated with potass, which retained the arsenic acid, and separated the other bodies. A precipitate of arseniat of cobalt, which had fallen when the nitric solution was diluted with water, was treated with potass for the same reason. The residuum, together with the precipitate occasioned by the potass, was dissolved in nitric acid, and ammonia added in excess. Part was retained in solution by the ammonia; but part was precipitated. The

precipitate was dissolved in acetous acid, and the solution repeatedly evaporated to dryness. By this process the oxide of iron gradually separated in the form of a red powder. The dissolved part was acetite of cobalt. It was decomposed by the addition of ammonia in excess, which redissolved the cobalt. By these processes the arsenic and iron were separated; the cobalt was retained by the ammonia, and was obtained by evaporation. To ascertain the proportion of sulphur in the ore a new portion was boiled with nitric acid. On cooling, crystals of white oxide of arsenic were deposited. These being separated, nitrat of barytes was added to the solution; 100 parts of the dried precipitate indicated 14.5 of sulphur*.

The other ores of cobalt may be analysed nearly in the same way.

XVI. Ores of Manganese.

Baryted manganese.

1. Barytated manganese was treated by Vauquelin with muriatic acid; oxy-muriatic gas passed over, and the whole was dissolved except a little charcoal and silica. The solution when evaporated yielded crystals of muriat of barytes. These were separated; and the liquid, evaporated to dryness, yielded a yellow mass soluble in alcohol, and tinging its flame with yellow brilliant sparks. The proportion of barytes was ascertained by precipitating it in the state of a sulphat; the manganese, by precipitating it by carbonat of potass†.

Grey ore of manganese.

2. The grey ore of manganese was treated by the same chemist with muriatic acid; some silica remained undissolved. Carbonat of potass was added to the solu-

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* *Ann. de Chim*, xxviii. 92.

† *Jour. de Min.* No. xix. 40.

tion. The precipitate was at first white, but became black when exposed to the air. It was treated with nitric acid, which dissolved every thing but the manganese and iron (if any had been present.) The nitric solution, when mixed with carbonat of potass, deposited only carbonat of lime. The black residuum was mixed with sugar, and treated with nitric acid. The solution was complete; therefore no iron was present.

The same processes will succeed with the other ores of manganese. When iron is present, it may be separated either as above, or by the rules laid down in the First Section of this Chapter.

XVII. Ores of Tungsten.

Wolfram;

1. Wolfram was analysed by the Elhuyarts, and by Vauquelin and Hecht, nearly as follows: The ore was boiled with muriatic acid, and then digested with ammonia alternately till the whole was dissolved. The ammoniacal solutions being evaporated to dryness and calcined, left the yellow oxide of tungsten in a state of purity. The muriatic solutions were mixed with sulphuric acid, evaporated to dryness, and the residuum redissolved in water. A little silica remained. Carbonat of potass precipitated a brown powder from this solution. This powder was treated with boiling nitric acid repeatedly, till the iron which it contained was oxidated to a maximum. It was then digested in acetous acid, which dissolved the manganese, and left the iron. Finally, the manganese was precipitated by an alkali.

Tungstat of lime.

2. Tungstat of lime may be treated with nitro-muriatic acid till every thing soluble is taken up. The residuum is yellow oxide of tungsten. Its purity may be tried by solution in ammonia. The nitro-muriatic so-

lution contains lime, and perhaps a little iron and alu mina. It may be examined by the rules laid down i the First Section of this Chapter.

XVIII. Ores of Molybdenum.

Molybdena.

Molybdena may be treated with nitric acid successively boiled upon it till it is converted into a whit powder. This powder, washed and dried, is molybdi acid The liquid obtained by washing the acid, on th addition of potass, deposites some more molybdic acid This being separated, muriat of barytes is to be drop into it as long as any precipitate appears. 100 parts o this precipitate indicate 14.5 of sulphur.

XIX. Ores of Uranium.

Pechblende.

1. Pechblende or the black ore of uranium was dissolved by Klaproth in nitric acid. The undissolve part is a mixture of silica and sulphur. By evaporating the solution, nitrat of lead was precipitated; the nitrated uranium in crystals. The solution being nov evaporated to dryness, and treated again with nitric acid left the iron in the state of red oxide.

Uranitic ochre.

2. Uranitic ochre may be treated with nitric acid which dissolves the uranium. and leaves the iron. Th purity of the iron may be tried by the rules already laid down.

Green mica.

3. Green mica was dissolved by Klaproth in nitric acid and ammonia added in excess to the solution. The oxide of uranium was precipitated; that of copper retained.

XX. Ores of Titanium.

The ores of titanium, reduced as usual to a fine powder, are to be fused with potass or its carbonat. The melted mass is then to be dissolved in hot water. A white precipitate gradually separates, which is the white oxide of titanium. This is all that is necessary to analyse the first species. But when iron and silica are present, the following method of Chenevix may be adopted. Saturate the alkaline solution with muriatic acid. White oxide of titanium precipitates. Separate the precipitate, and evaporate the solution to dryness. Redissolve the residuum in water. The silica remains behind. Precipitate the solution by an alkali; add the precipitate to the white oxide obtained at first, and dissolve the whole in sulphuric acid. From this solution phosphoric acid precipitates the titanium, but leaves the iron*.

Menachanite.

The third species, which contains lime and no iron, is to be fused with potass, dissolved in muriatic acid, and the silica separated in the usual way. After this the titanium is first to be separated from the muriatic solution by ammonia; and afterwards the lime by an alkaline carbonat.

XXI. Ores of Chromum.

Chromat of lead.

1. Vauquelin analysed the chromat of lead in the following manner: When boiled with a sufficient quantity of carbonat of potass, a lively effervescence takes place; the acid combines with the potass, and the carbonat of lead is formed, and remains undissolved. It may be dissolved in nitric acid, and its quantity ascertained by precipitation with sulphuric acid. Or the chromat may be treated with muriatic acid; muriat of lead precipitates, and chromic acid remains in solution. This process

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* Nicholson's *Journal*, v. 132.

Book III.

must be repeated till the whole of the ore is decomposed. There remains in solution chromic acid mixed with a little muriatic, which may be separated by means of oxide of silver.

Chromat of iron.

2. Tassaert analysed the chromat of iron as follows: It was melted with eight times its weight of potass in a crucible. The resulting mass dissolved in water except a brown powder. This residuum was treated with muriatic acid, which dissolved a part of it. The residuum was treated as at first with potass and muriatic acid, till the whole was dissolved. The alkaline solution contained the chromic acid; the muriatic solution, the iron, still mixed with a little chromum. It was precipitated by potass, and the precipitate boiled with that alkali, to separate the whole of the chromic acid. What remained was pure oxide of iron. The chromic solutions were saturated with nitric acid, and mixed with nitrat of lead. The resulting precipitate indicated the proportion of chromic acid; for 100 parts of chromat of lead indicate about 35 of chromic acid.

SECT. IV.

METHOD OF OBTAINING PURE METALS.

The method of analysing the different ores with precision being ascertained, we have it in our power to obtain the metals in a state of purity, which is often nessary for chemical purposes. In this Section I shall give a short view of the processes commonly employed for that purpose.

1. *Gold*. To obtain pure gold, we have only to dissolve the gold of commerce in nitro-muriatic acid, and precipitate the metal by dropping in a very diluted solution of sulphat of iron; the powder which precipitates, after being well washed and dried, is pure gold.

2. *Platinum*. Platinum can scarcely be obtained perfectly pure in the metallic state, at least in any considerable quantity; because a sufficient heat for melting it cannot be obtained. But its oxide may be procured quite pure from the muriat of platinum and ammonia, prepared by the rules laid down in the last Section. This salt is to be decomposed by a violent heat, and the residuum, if necessary, may be redissolved in nitro-muriatic acid, and precipitated with soda.

3. *Silver*. Dissolve the silver of commerce in nitric acid, and precipitate with a diluted solution of sulphat of iron. The precipitate is pure silver. Or precipitate with common salt; form the precipitate into a paste with soda; put it into a crucible lined with soda, and fuse it with a brisk heat. This process gives a button of pure silver.

4. *Mercury* may be obtained pure by distilling a mixture of two parts cinnabar and one part iron-filings in an iron retort. The mercury comes over, and the sulphuret of iron remains behind; or the oxy-muriat of mercury may be decomposed by ammonia, and the precipitate heated either by itself or mixed with oil.

5. *Copper* may be dissolved in muriatic acid, and the copper precipitated by a polished plate of iron; or the black oxide of copper, obtained by decomposing cuprated ammonia, may be melted with its own weight of pounded glass and pitch.

6. *Iron* can scarcely be obtained perfectly free from

carbon. The processes described in a former part of this Work furnish it as pure as it can be procured

7. *Tin* may be obtained pure by solution in strong nitric acid; the white oxide of tin is formed, which is insoluble. Let it be digested first with muriatic acid, and afterwards with aqua regia. Mix the oxide thus purified with its weight of pitch and a little borax, and melt it in a crucible.

8. *Lead* may be dissolved in nitric acid, and precipitated by sulphat of soda; wash the precipitate, and melt it in a crucible with 2½ times its weight of black flux.

9. *Nickel* may be obtained pure from kupfer nickel, by roasting the ore previously mixed with charcoal; dissolving it in nitric acid, evaporating the solution to dryness, redissolving it in water, precipitating by potass, and boiling the precipitate with potass. The precipitate is then to be edulcorated, dissolved in acetous acid, the solution evaporated to dryness, redissolved in water, and precipitated by ammonia in excess, which redissolves the oxides of cobalt and nickel. By evaporating this solution the cobalt is precipitated, and the solution becomes blue. This last solution, evaporated to dryness, gives pure oxide of nickel. Form this oxide into a paste with oil, mix it with two or three parts of black flux, and put it into a crucible, covering it up with borax and common salt. Heat the crucible violently for an hour and a half in a smith's forge. A button of pure nickel is obtained.

10. *Zinc* may be dissolved in sulphuric acid, and a plate of zinc allowed to remain for a considerable time in the solution, It is then to be filtered, and the zinc to be precipitated with soda. The precipitate, edulcorated and dried, is to be mixed with half its weight of

pure charcoal, and distilled in an earthen ware retort. The zinc is found pure in the neck of the retort.

11. *Antimony* may be dissolved in nitro-muriatic acid, and precipitated by the affusion of water. The precipitate is to be mixed with twice its weight of tartar, and fused in a crucible. A button of pure antimony is obtained.

12. *Bismuth*, if impure, may be dissolved in nitric acid, and precipitated by water. The edulcorated precipitate, formed into a paste with oil, and rapidly fused with black flux, gives a button of pure bismuth.

13. *Tellurium* was obtained pure by Klaproth, by forming its oxide into a paste with oil, and heating it to redness in a retort. The metal was rapidly revived.

14. *Arsenic*, in the state of white oxide, may be dissolved in muriatic acid, precipitated by the affusion of water, redissolved, and a plate of zinc inserted into the solution, mixing with it at the same time a little alcohol. The arsenic is precipitated in the metallic state.

15. *Cobalt* ores ought to be roasted for some time, adding occasionally a little charcoal or oil to favour the evaporation of the arsenic. They are then to be dissolved in nitric acid, the solution evaporated to dryness, and redissolved in water. The solution is to be precipitated by potass, and the precipitate boiled with that alkali. It is then to be edulcorated, dissolved in acetous acid, the solution evaporated to dryness, and redissolved in water. Precipitate by ammonia, and redissolve the precipitate in ammonia. Evaporate the ammoniacal solution to dryness. Mix the oxide thus obtained with oil and black flux, pour it into a crucible, cover it with borax, and expose it for an hour and a half to the heat of a forge. A pure button of cobalt is obtained.

16. *Manganese.* Digest the black oxide of manganese repeatedly in nitric acid; then mix it with sugar and dissolve it in nitric acid. Filter the solution, precipitate by an alkali, form the white oxide thus obtained into a paste with oil, and put it into a crucibl well-lined with charcoal. Expose the crucible for an hour to the strongest heat of a forge.

17. *Tungsten* was obtained by Elhuyart by heating the yellow oxide violently in a crucible lined with charcoal: but this process has not succeeded with other chemists.

18. *Molybdenum* may be obtained by forming molybdic acid into a paste with oil, and heating it violently in a crucible lined with charcoal.

19. *Uranium* is procured by forming the yellow oxide of that metal into a paste with oil, drying it in a moderate heat, putting it into a crucible lined with charcoal, with a little lamp-black strewed over it. After luting on the cover, it is to be heated at first gently, and then violently for three quarters of an hour.

20. *Titanium*, in a very small proportion indeed, was obtained in the metallic state by mixing together 100 parts of the red oxide of the metal, 50 parts of borax, and 5 parts of charcoal, and forming the mixture into a paste with oil. This paste was put into a crucible lined with charcoal, and exposed for an hour and a half to the violent heat of a forge*.

21. *Chromum* was obtained by Vauquelin in the metallic state, by putting a portion of chromic acid into a charcoal crucible, inclosed in a common crucible lined with charcoal, and exposing it for an hour to the violent heat of a forge.

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* A heat of 166° W.—See Vauquelin and Hecht, *Jour. de Min.* No. xv. 23.

BOOK IV.

OF

VEGETABLES.

VEGETABLES are too well known to require any definition. They are perhaps the most numerous class of bodies belonging to this globe of ours; the species already known amounting to no less than 40,000, and very considerable additions are daily making to the number. But it is not my intention in this place either to enumerate, to describe, or to classify plants. These tasks belong to the botanist, and have been successfully accomplished by the zeal, the singular address, and the indefatigable labour of Linnæus and his followers.

Chemical examination of plants.

It is the business of the chemist to analyse vegetables, to discover the substances of which they are composed, to examine the nature of these substances, to investigate the manner in which they are combined, to detect the processes by which they are formed, and to ascertain the chemical changes to which plants, after they have ceased to vegetate, are subject. Hence it is evident that a chemical investigation of plants comprehends three particulars: 1. An account of the *substances* of which plants are composed. 2. An account of

Book IV.

the *vegetation* of plants, as far as it can be illustrate by chemistry. 3. An account of the *changes* whic plants undergo after they cease to vegetate. These shal form the subject of the three following Chapters.

CHAP. I.

OF THE INGREDIENTS OF PLANTS.

THE substances hitherto found in the vegetable kingdom, all of them at least which have been examine with any degree of accuracy, may be reduced under th following heads:

Vegetable substances.

I. *Soluble in water.*
  1. Sugar,
  2. Gum,
  3. Jelly,
  4. Starch
  5. Albumen,
  6. Extract,
  7. Tan,
  8. Acids,
  9. Alkalies.
II. *Oils and their products.*
  10. Oils,
  11. Wax and tallow,
  12. Resins,
  13. Camphor.
III. *Glutinous.*
  14. Gluten,
  15. Caoutchouc.
IV. *Woody.*
  16. Wood,
  17. Suber.
V. *Earthy and metallic.*
  18. Earths,
  19. Metals.

The properties of these different classes of bodies shal be examined in the following Sections.

SECT. I.

OF SUGAR.

History.

Sugar, which at present forms so important an article in our food, seems to have been known at a very early period to the inhabitants of India and China. But Europe probably owes its acquaintance with it to the conquests of Alexander the Great. For ages after its introduction into the west, it was used only as a medicine; but its consumption gradually increased; and during the time of the Crusades, the Venetians, who brought it from the east, and distributed it to the northern parts of Europe, carried on a lucrative commerce with sugar. It was not till after the discovery of America, and the extensive cultivation of sugar in the West Indies, that its use in Europe, as an article of food, became general *.

How obtained.

Sugar is obtained from the *arundo saccharifera*, or *sugar cane*. The juice of this plant is pressed out and boiled rapidly in large vessels to the consistence of a syrup. On cooling, it partly concretes into fine crystalline grains like sand, which do not cohere together; and remains partly in the state of a black thick syrup. This last is made to run off, and is well known under the name of *molasses*. The crystalline grains have a

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* See Falconer's Sketch of the History of Sugar, *Manchester Memoirs*, iv. 291. and Mozeley's *History of Sugar*.

brownish colour. They are imported into Europe under the name of *raw sugar*. They are farther refined by solution in water and clarification. The syrup properly boiled down is poured into cones with their apexes downwards, and covered with a layer of moist clay. The water filtering downwards carries off the impurities, and leaves a fine white hard mass, commonly called *loaf sugar* *.

Properties.

Sugar has a very strong sweet taste; when pure it has no smell; its colour is white, and when crystallized it is somewhat transparent. It has often a considerable degree of hardness; but it is always so brittle that it can be reduced without difficulty to a very fine powder. When two pieces of sugar are rubbed against each other in the dark, a strong phosphorescence is visible.

Sugar is not altered by exposure to the atmosphere, excepting only that in damp air it absorbs a little moisture.

Solubility in water.

It is exceedingly soluble in water. At the temperature of 48°, water, according to Mr Wenzel, dissolves its own weight of sugar. The solvent power of water increases with is temperature; when nearly at the boiling point, it is capable of dissolving any quantity of sugar whatever. Water thus saturated with sugar is known by the name of *syrup*.

Syrup.

Syrup is thick, ropy, and very adhesive; when spread thin upon paper, it soon dries, and forms a kind

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[*] I have purposely avoided entering into any detail respecting the preparation of sugar, because the theory of the process is altogether unknown, and must remain so till the component parts of the sugar cane juice be ascertained, and the changes occasioned in them by boiling be discovered.

of varnish, which is easily removed by water. Its specific caloric, according to the experiments of Dr Crawford, is 1.086. When syrup is sufficiently concentrated, the sugar which it contains precipitates in crystals. The primitive form of these crystals is a four-sided prism, whose base is a rhomb, the length of which is to its breadth as 10 to 7; and whose height is a mean proportion between the length and breadth of the base. The crystals are usually four or six sided prisms, terminated by two-sided, and sometimes by three-sided summits *.

Crystals.

Solubility in alcohol.

Sugar is soluble in alcohol, but not in so large a proportion as in water. According to Wenzel, four parts of boiling alcohol dissolve one of sugar †. It unites readily with oils, and renders them miscible with water. A moderate quantity of it prevents, or at least retards, the coagulation of milk; but Scheele discovered that a very large quantity of sugar causes milk to coagulate ‡.

Action of acids.

The only acids whose action on sugar has been examined are the sulphuric and nitric. Sulphuric acid, when concentrated, readily decomposes sugar; water is formed, and perhaps also acetous acid; while charcoal is evolved in great abundance, and gives the mixture a black colour, and a considerable degree of consistency. The charcoal may be easily separated by dilution and filtration. When heat is applied the sulphuric acid is rapidly converted into sulphurous acid.

Nitric acid dissolves it with an effervescence, occasioned by the evolution of nitrous gas, and converts it

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* Gillot, *Ann. de Chim.* xviii. 317.

† *Encycl. Meth. Chim.* i. 271.

‡ Scheele, ii. 32. Dijon Trans.

into malic and oxalic acids. No substance undergoe these changes so readily as sugar. Hence it is usuall employed for procuring oxalic acid.

Sugar absorbs muriatic acid gas slowly, and assume a brown colour and very strong smell*. The action o oxy-muriatic acid on sugar has not been tried. Th vegetable acids dissolve it; but seemingly without producing any alteration in it.

Action of potass,

When sugar is mixed with potass, the mixture acquires a bitter and astringent taste, and is insoluble i alcohol, though each of the ingredients is very solubl in that liquid. When the alkali is saturated with sulphuric acid, and precipitated by means of alcohol, th sweet taste of the sugar is restored; a proof that it had undergone no decomposition from the action of the potass, but had combined with it in the state of sugar †.

Of lime.

Lime boiled with sugar produces nearly the same effect as potass: when an alkali is added to the compound, a substance precipitates in white flakes. This substance is sugar combined with lime ‡. Sugar and chalk compose, as Leonardi informs us, a kind of cement §.

Action of heat.

Sugar, when thrown upon a hot iron, melts, swells, becomes brownish black, emits air bubbles, and exhales a peculiar smell, known in French by the name of *caromel.* At a red heat it instantly bursts into flames with a kind of explosion. The colour of the flame is white with blue edges.

Distillation of sugar.

When sugar is distilled in a retort, there comes over a fluid which, at first, scarcely differs from pure water;

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* Priestley, ii. 291.

† Cruickshank, Rollo, *on Diabetes*, p. 452.

‡ Ibid.

§ *Encycl. Meth. Chim.* i. 271.

by and bye it is mixed with what was formerly called pyromucous acid, and is now known to be a compound of oil and acetous acid*; afterwards some empyreumatic oil makes its appearance, and a bulky charcoal remains in the retort. This charcoal very frequently contains lime, because lime is used in refining sugar; but if the sugar, before being submitted to distillation, be dissolved in water, and made to crystallize by evaporation in a temperature scarcely higher than that of the atmosphere, no lime whatever, nor any thing else, except pure charcoal, will be found in the retort. During the distillation, there comes over a considerable quantity of carbonic acid and carbonated hydrogen gas †. Sugar therefore is decomposed by the action of heat; and the following compounds are formed from it: Water, acetous acid, oil, charcoal, carbonic acid, carbonated hydrogen gas. The quantity of oil in a separate state is inconsiderable; by far the most abundant product is pyromucous acid. Sugar indeed is very readily converted into pyromucous acid; for it makes its appearance always whenever syrup is raised to the boiling temperature. Hence the smell of caromel, which syrup at that temperature emits. Hence also the reason that, when we attempt to crystallize syrup by heat, there always remains behind a quantity of incrystallizable matter, known by the name of *molasses;* whereas if the syrup be crystallized without artificial heat, every particle of sugar may be obtained from it in a crystalline form ‡. Hence we see the importance of properly re-

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* For this interesting discovery, we are indebted to the experiments of Fourcroy and Vauquelin.

† Scopoli and Morveau, *Encycl. Meth. Chim.* i. 269.

‡ Morveau, *Encycl. Meth. Chim.* i. 266.

gulating the fire during the crystallization of the sugar, and the saving that would probably result from conducting the operation at a low heat.

Its component parts.

It follows from these facts, and from various other methods of decomposing sugar, that it is composed of oxygen, hydrogen, and carbon; for all the substances obtained from sugar by distillation may be resolved into these elements. Lavoisier has made it probable, by a series of very delicate experiments on the vinous fermentation, that these substances enter into the composition of sugar in the following proportions:

64	oxygen
28	carbon
8	hydrogen
100	

But these proportions can only be considered as approximations to the truth.

Plants containing it.

Sugar is considered as a very nourishing article of food. It is found most abundantly in the juice of the sugar cane, but many other plants also contain it. The juice of the acer saccharinum, or *sugar maple,* contains so much of it, that in North America sugar is often extracted from that tree *. Sugar is also found in the roots of carrot, parsnip, beet, &c. Mr Achard has lately pointed out a method of increasing the quantity of sugar in beet so much, that, according to his own account, it is at present cultivated in large quantities in Prussia, and sugar extracted from it with advantage †. Parmentier has also ascertained that the grains of wheat, barley, &c. and all the other similar seeds

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* Rush, *Trans. Philad.* iii. 64.

† *Ann. de Chim.* xxxii. 163.

which are used as food, contain at first a large quantity of sugar, which gradually disappears as they approach to a state of maturity. This is the case also with peas and beans, and all leguminous seeds; and is one reason why the flavour of young peas is so much superior to that of old ones.

How extraced from plants.

Sugar may be extracted from many vegetables by pounding them and digesting them in alcohol. The alcohol dissolves the sugar, and yields it in crystals by evaporation. This method was first pointed out by Margraff. The nature of the other sweet-tasted bodies analogous to sugar has not been hitherto ascertained by chemists. It is believed at present that *honey* is sugar combined with an acid, and perhaps some gummy matter. *Manna*, a gummy juice which exudes from a variety of trees, is supposed to be sugar combined with a nauseous tasted extract. Goettling obtained a similar substance from the beet *.

SECT. II.

OF GUM.

How obtained.

THERE is a thick transparent tasteless fluid which sometimes exudes from certain species of trees. It is very adhesive, and gradually hardens without losing its transparency; but easily softens again when moistened with water. This exudation is known by the name of *gum*. The gum most commonly used is that which ex-

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* *Phil. Mag.* ix. 184.

udes from different species of the *mimosa*, particularly the *nilotica* *. It is known by the name of *gum arabic*. Gum likewise exudes abundantly from the *prunus avium*, or common wild cherry tree of this country.

Gum is usually obtained in small pieces like tears, moderately hard, and somewhat brittle while cold, so that it can be reduced by pounding to a fine powder.

Properties.

When pure it is colourless, but it has usually a yellowish tinge, and it is not destitute of lustre. It has no smell. Its tase is insipid. Its specific gravity varies from 1.3161 to 1.4817.

Solution in water.

Gum undergoes no change from being exposed to the atmosphere; but the light of the sun makes it assume a white colour. Water dissolves it in large quantities. The solution which is known by the name of *mucilage* †, is thick and adhesive: it is often used as a paste, and to give stiffness and lustre to linen. When spread out thin it soon dries, and has the appearance of a varnish; but it readily attracts moisture, and becomes glutinous.

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* Schousbae, *Phil. Mag.* v. 241.

† Hermstadt uses this word in a different sense. He makes a distinction between *gum* and *mucilage*. The solution of *gum* in water is transparent and glutinous, and can be drawn out into threads; whereas that of *mucilage* is opaque, does not feel glutinous, but slippery, and cannot be drawn into threads. Gum may be separated from mucilage by the following process:

Let the gum which is supposed to be mixed with mucilage, previously reduced to a dry mass, be dissolved in as small a quantity of water as possible, and into the solution drop at intervals diluted sulphuric acid. The mucilage coagulates, while the gum remains dissolved. When no more coagulation takes place, let the mixture remain at rest for some time, and the mucilage will precipitate to the bottom, and assume the consistence of jelly. Decant off the liquid part, and evaporate the mucilage to dryness by a gentle heat till it acquires the consistence of horn. *Med.* and *Phys. Jour.* iii. 370.

Water washes it away entirely. When mucilage is evaporated the gum is obtained unaltered. This mucilaginous solution may be kept for years without undergoing putrefaction. Scarcely any vegetable substance is less liable to decomposition. At last, however, the odour of acetous acid becomes perceptible in it.

Action of alcohol.

Gum is insoluble in alcohol. When alcohol is poured into mucilage, the gum immediately precipitates; because the affinity between water and alcohol is greater than that between water and gum.

Action of acids,

The vegetable acids dissolve gum without alteration; the strong acids decompose it. Sulphuric acid converts it into water, acetous acid, and charcoal. The same effect is said by Fourcroy to be produced by muriatic acid. Oxy-muriatic acid, according to Vauquelin, converts it into citric acid [*]. If nitric acid be slightly heated upon gum till it has dissolved it, and till a little nitrous gas is exhaled, the solution on cooling deposits mucous acid. Malic acid is formed at the same time; and if the heat be continued, the gum is at last changed into oxalic acid. Thus no less than three acids are developed by the action of nitric acid on gum [†].

Of alkalies and earths,

The effect of the alkalies and earths on gum has not been examined with attention. Mr Woulfe observed that gum, when distilled with a fixed alkali, yields more oil than when distilled by itself. Several metallic solutions have the property of occasioning a precipitate in mucilage; the precipitate is a combination of the oxide and the gum, and the oxide is usually at the same time brought nearer the metallic state.

Of heat.

When gum is exposed to heat it softens and swells,

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[*] *Ann. de Chim.* vi. 178.

[†] Fourcroy, vii. 148.

but does not melt; it emits air bubbles, blackens, and at last, when nearly reduced to charcoal, emits a low blue flame. This flame appears sooner if a flaming substance be held just above the gum. After the gum is consumed, there remains a small quantity of white ashes, composed chiefly of the carbonats of lime and potass.

Distillation of gum.

When gum is distilled in a retort, the products are water impregnated with a considerable quantity of pyro-mucous acid or *acetous acid* combined with oil, a little empyreumatic oil, carbonic acid gas, and carbonated hydrogen gas. When the pyromucous acid obtained by this process is saturated with lime, a quantity of ammonia is disengaged with which that acid had been combined. The charcoal which remained in the retort leaves behind it, after incineration, a little lime, and phosphat of lime *.

Its component parts.

These experiments shew us that gum is composed chiefly of hydrogen, carbon, and oxygen, and that it contains also azot, lime, and phosphorus. Mr Cruickshank has rendered it probable that the quantity of carbon is greater, and the quantity of oxygen less, in gum than in sugar †. Fourcroy and Vauquelin inform us, that their experiments give the component parts of gum as follows . . . 65.38 oxygen
23.08 carbon
11.54 hydrogen

100.00 ‡

Gum, or mucilage, exists most abundantly in young plants, and gradually disappears as they arrive at perfec-

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* Cruickshank, Rollo on *Diabetes*. † Ibid. ‡ Fourcroy, vii. 153.

tion. It forms a great proportion of the leaves and roots of many eatable plants.

SECT. III.

OF JELLY.

How obtained.

If we press out the juice of ripe blackberries, currants, and many other fruits, and allow it to remain for some time in a state of rest, it partly coagulates into a tremulous soft substance, well known by the name of *jelly*. If we pour off the uncoagulated part, and wash the coagulum with a small quantity of water, we obtain *jelly* approaching to a state of purity.

Properties.

In this state it is nearly colourless, unless tinged by the peculiar colouring matter of the fruit; it has a pleasant taste, and a tremulous consistency. It is scarcely soluble in cold water, but very soluble in hot water; and, when the solution cools, it again coagulates into the form of a jelly [*]. When long boiled, it loses the property of gelatinising by cooling, and becomes analagous to mucilage [†], This is the reason that in making currant jelly, or any other jelly, when the quantity of sugar added is not sufficient to absorb all the watery parts of the fruit, and consequently it is necessary to concentrate the liquid by long boiling, the mixture often loses the property of coagulating, and the jelly, of course, is spoiled [‡].

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[*] Vauquelin, *Ann. de Chim.* vi. 282.

[†] Id. Ibid. v. 100.

[‡] *Ann. de Chim.* v. 102.

Jelly combines readily with alkalies; nitric acid converts it into oxalic acid, without separating any azotic gas[*]. When dried it becomes transparent[†]. When distilled it affords a great deal of pyromucous acid, a small quantity of oil, and scarcely any ammonia[‡].

Plants containing it.

Jelly exists in all acid fruits, as oranges, lemons, gooseberries, &c. If the juices of these fruits be allowed to gelatinize, and then poured upon a searce, the acid gradually filters through, and leaves the other; which may be washed with a little cold water, and allowed to dry. Its bulk gradually diminishes, and it concretes into a hard transparent brittle mass, which possesses most of the properties of gum. Perhaps, then, jelly is merely gum combined with vegetable acid.

SECT. IV.

OF STARCH.

How obtained.

If a quantity of wheat flour be formed into a paste, and water poured upon it till it runs off colourless, this water soon deposites a very fine whitish powder; which, when properly washed and dried, is known by the name of *starch*. When first prepared, it is of a grey colour; but the starchmakers render it white by steeping it in water slightly acidulated. The acid seems to dissolve and carry off the impurities. Starch for common use is prepared from wheat flour, which is made to undergo a kind of fermentation.

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[*] *Ann. de Chim.* vi. 282.

[†] Ibid. v. 100.

[‡] Ibid. vi. 286.

Starch was well known to the ancients. Pliny informs us, that the method of obtaining it was first invented by the inhabitants of the island of Chio *.

Properties.

Starch has a fine white colour, and is usually concreted in longish masses; it has scarcely any smell, and very little taste. When kept dry, it continues for a long time uninjured though exposed to the air.

Solution in water.

Starch does not dissolve in cold water, but very soon falls to powder, and forms with it a kind of emulsion. It combines with boiling water, and forms with it a thick paste. Linen dipt into this paste, and afterwards dried suddenly, acquires, as is well known, a great degree of stiffness. When the paste is allowed to cool, it assumes the form of a semi-transparent jelly; which, when dried by artificial heat, becomes brittle, and assumes an appearance not unlike that of gum. Hence it is supposed that starch, by being boiled in water, undergoes a certain degree of decomposition which brings it nearly to the state of gum. When this paste is left exposed to damp air it soon loses its consistency, acquires an acid taste, and its surface is covered with mould.

Action of alcohol.

Starch is so far from dissolving in alcohol, even when assisted by heat, that it does not even fall to powder.

Action of acids.

When starch is thrown into any of the mineral acids, at first no apparent change is visible: But if an attempt is made to reduce the larger pieces while in acids to powder, they resist it, and feel exceedingly tough and adhesive. Sulphuric acid dissolves it slowly, and at the same time a smell of sulphurous acid is emitted; and such a quantity of charcoal is evolved, that the vessel containing the mixture may be inverted without spil-

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* Lib. xviii. c. 7.

ling any of it. Indeed if the quantity of starch be sufficient, the mixture becomes perfectly solid. The charcoal may be separated by dilution and filtration. In muriatic acid starch dissolves still more slowly. The solution resembles mucilage of gum arabic, and still retains the peculiar odour of muriatic acid. When allowed to stand for some time, the solution gradually separates into two parts; a perfectly transparent straw-coloured liquid below, and a thick, muddy, oily, or rather mucilaginous substance, above. When water is poured in, the muriatic smell instantly disappears, and a strong smell is exhaled, precisely similar to that which is felt in cornmills. Ammonia occasions a slight precipitate, but too small to be examined.

Nitric acid dissolves starch more rapidly than the other two acids; it acquires a green colour, and emits nitrous gas. The solution is never complete, nor do any crystals of oxalic acid appear unless heat be applied. In this respect starch differs from sugar, which yields oxalic acid with nitric acid, even at the temperature of the atmosphere. When heat is applied to the solution of starch in nitric acid, both oxalic and malic acid is formed, but the undissolved substance still remains. When separated by filtration, and afterwards edulcorated, this substance has the appearance of a thick oil, not unlike tallow; but it dissolves readily in alcohol. When distilled, it yields acetous acid, and an oil having the smell and the consistence of tallow *.

Of alkalies,

The alkalies dissolve starch, but do not seem to decompose it, except when very much concentrated and assisted by heat.

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* Scheele, Crell's *Annals*, ii. 14. Eng. Trans.

Of heat.

When starch is thrown upon a hot iron, it melts, blackens, froths, swells, and burns with a bright flame like sugar, emitting, at the same time, a great deal of smoke; but it does not explode, nor has it the caromel smell which distinguishes burning sugar. When distilled, it yields water impregnated with an acid, supposed to be the pyromucous, a little empyreumatic oil, and a great deal of carbonic acid and carbonated hydrogen gas. The charcoal which remains is easily dissipated when set on fire in the open air; a proof that it contains very little earth.

Composition.

Barley grain consists almost entirely of starch, not however in a state of perfect purity. In the process of malting, which is nothing else than causing the barley to begin to vegetate, a great part of the starch is converted into sugar. During this process oxygen gas is absorbed, and carbonic acid gas is emitted. Water, too, is absolutely necessary: hence it is probable, that it is decomposed, and its hydrogen retained *. Starch, then, seems to be converted into sugar by diminishing the proportion of its carbon, and encreasing that of its hydrogen and oxygen. Its distillation shews us that it contains no other ingredient than these three.

Plants containing it.

Starch is contained in a great variety of vegetable substances; most commonly in their seeds or bulbous roots; but sometimes also in other parts. Mr Parmentier, whose experiments have greatly contributed towards an accurate knowledge of starch, has given us the following list of the plants from the roots of which it may be extracted.

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* Cruikshank, Rollo on *Diabetes*.

Arctium lappa,
Atropa belladonna,
Polygonum bistorta,
Bryonia alba,
Colchicum autumnale,
Spiræa filipendula,
Ranunculus bulbosus,
Scrophularia nodosa,
Sambucus ebulus,
——— nigra,
Orchis morio,
Imperatoria ostrutheum,
Hyoscyamus niger,
Rumex obtusifolius,
——— acutus,
——— aquaticus,
Arum maculatum,
Orchis mascula,
Iris pseudacorus,
— fœtidissima,
Orobus tuberosus,
Bunium bulbocastanum.

It is found also in the following seeds:

Oats,
Rice,
Maiz,
Millet,
Chesnut,
Horsechesnut,
Peas,
Beans,
Acorn,
And also in
Salop,
Sago.

Indeed the greater number, if not the whole, of the vegetable seeds employed by man as an article of food, consists chiefly of starch. But that substance is almost always combined with some other which serves to disguise its properties; such as sugar, oil, extract, &c. The late experiments of Lord Dundonald on the gum that may be extracted from lichens, is a confirmation of a fact formerly suspected by chemists; namely, that many lichens (the *islandicus*, for instance) are composed chiefly of starch.

SECT. V.

OF ALBUMEN.

How obtained.

If the water in which wheat flour has been washed in order to obtain starch, according to the directions laid down in the last Section, be filtrated, and afterwards evaporated, a substance precipitates in white flakes; to which Mr Fourcroy, who first pointed it out, has given the name of *albumen* [*], on account of its resemblance to the *white* of an egg [†].

Properties.

It is evident, from the method of obtaining it, that albumen, in its natural state, is soluble in water, and that heat precipitates it from that fluid in a concrete state. While dissolved in water it has scarcely any taste; but it has the property of changing vegetable blues, especially that which is obtained from the flowers of the mallow (*malva sylvestris*), into a green [‡]. When allowed to remain dissolved in water, it putrefies without becoming previously acid [§].

After it has been precipitated from water in a concrete state by boiling, it is no longer soluble in water as before. Alcohol also and acids precipitate it from water precisely in the same state as when it is precipitated by heat.

When concrete albumen is dried, it becomes somewhat transparent, and very like glue. In that state it is soluble in alkalies with facility.

Composition.

When distilled it gives out carbonat of ammonia, a red fetid oil, and carbonated hydrogen gas; and a spongy charcoal remains behind [||]. From this it is evident that albumen is composed of carbon, azot, hydrogen, and oxygen; but the proportions and combinations of these substances are altogether unknown.

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[*] The existence of albumen in vegetables was known to Scheele. He mentions it particularly in his Paper on Milk, first published in the year 1780. See Scheele's Works, ii. 55. Dijon Edition.

[†] *Ann. de Chim.* iii. 259. [‡] Fourcroy, ibid. 257. [§] Ibid. [||] Ibid.

Plants containing it.

Mr Fourcroy found albumen in the expressed juic of scurvy grass, cresses, cabbage, and almost all cruciform plants. Hence the reason that these plants, whe they putrefy, exhale such an abominable odour. H found it, too, in a great many young and succulen plants; but never a particle in those parts of vegetables which contain an acid. He observed also tha the quantity decreased constantly with the age of the plant. His method of extracting the albumen was to express the juice from the plants, to expose it for som time to the air, and then to filter it, in order to separate the green coloured fecula. The vessel containing it was then plunged into boiling water, which coagulated the albumen, and made it precipitate in flakes.

SECT. VI.

OF EXTRACT.

How obtained.

THE word *extract* was at first applied to all those substances which were extracted from plants by means of water, and which remained behind in the state of a dry mass when the water was evaporated; consequently it included gum, jelly, and several other bodies. But of late it has been confined, by those chemists who have paid attention to the use of language, to a substance which exists in many plants, and which may be obtained by infusing *saffron* in water for some time, filtrating the infusion, and evaporating it to dryness. The residuum, after evaporation, is *extract* nearly pure*. It possesses the following properties:

Water dissolves it in considerable quantities, espe-

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* Hermstadt.

cially hot water. Alcohol also dissolves it with facility. This property of being soluble both in water and alcohol has induced some chemists to give *extract* the name of *soap*. It is insoluble in sulphuric ether. These three properties are sufficient to distinguish it from every other vegetable substance *.

Properties.

When the solution of extract in water is exposed for some time in the open air, the extract assumes a brown colour, precipitates to the bottom, and is now no longer soluble in water. This change is supposed to proceed from the addition of a quantity of oxygen which it imbibes from the atmosphere †.

When oxy-muriatic acid is poured into a watery solution of extract, that substance precipitates in yellow flakes. These flakes are insoluble in water; they are insoluble also in alcohol at the temperature of 97°; but that liquid dissolves them at the temperature of 120°. They are soluble also in alkalies; and in boiling hot water they melt into a yellow mass ‡.

Extract is soluble in acids. Heat softens but does not melt it §. There is a strong affinity betwen it and alumina: when sulphat of alumina is boiled in a liquid containing extract, the alumina precipitates combined with the extract. The solution of tin also, and of several other metallic oxides, precipitate the extract combined with the metal ¶.

Plants containing it.

It is found in a great variety of plants; but as no method of obtaining it perfectly pure has hitherto been discovered, the extracts of different plants differ somewhat from each other both in their colour and smell.

It is contained abundantly in the sap of all plants.

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* Hermstadt. † Fourcroy. ‡ Id.

§ Id. *Ann. de Chim.* viii. ¶ Vauquelin.

As it cannot easily be procured separate, its component parts have not been determined. The experiments which have been made indicate the presence of oxygen, carbon, hydrogen, and azot.

SECT. VII.

OF TAN.

How procured.

If a quantity of nutgalls, coarsely powdered, be kept for some time infused in water, so as to form the common infusion of galls; if this infusion be somewhat concentrated by evaporation, and then mixed with a saturated solution of carbonat of potass, a yellowish white matter precipitates to the bottom in the form of flakes. This precipitate, washed with a little cold water, and then dried, is the substance known by the name of *tan*.

Properties.

Tan, thus obtained, is in the form of a glutinous paste, of a yellowish grey colour, and is not dried without difficulty; but when exposed to the heat of a stove, it melts at first, and then dries, and at last assumes the appearance of resin *. Tan was first discovered by Seguin, who pointed out some of its properties, and the method of ascertaining its existence in plants by the précipitate which it forms with the solution of glue in water; but it is to Proust that we are indebted for the investigation of its properties.

Tan is a brittle substance, of a brown colour. It breaks with a vitreous fracture, and does not attract

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* Proust, *Ann. de Chim.* xxxv. 33.

moisture from the air. Its taste is exceedingly astringent. It is very soluble in water. The solution is of a deep brown colour, a very astringent and bitter taste, and has the odour which distinguishes a solution of nutgalls. It froths, when agitated, like a solution of soap; but does not feel unctuous. Acids precipitate the tan from this solution. Acids precipitate it also from the infusion of nutgalls when sufficiently concentrated. Proust has laid hold of this property to procure pure tan. From the precipitate thus obtained, which has the consistence of pitch, the liquid part is to be decanted, and the precipitate, after being washed with a little cold water, is dissolved in boiling water, and the acid saturated with carbonat of potass. The tan precipitates in a state of purity.

Tan is still more soluble in alcohol than in water.

When the solution of tan is poured into a solution of the oxy-sulphat of iron, a deep blue-coloured precipitate immediately appears, consisting of the tan combined with the oxide. This precipitate, when dried, assumes a black colour. It is decomposed by acids. The sulphat of iron is not altered by tan.

When too great a proportion of oxy-sulphat of iron is poured into a solution of tan, the sulphuric acid, set at liberty by the combination of the iron and tan, is sufficient to redissolve the precipitate as it appears; but the precipitate may easily be obtained by cautiously saturating this excess of acid with potass. When the experiment is performed in this manner, all the oxy-sulphat of iron which remains in the solution undecomposed is converted into sulphat. Mr Proust supposes that this change is produced by the tan absorbing oxygen from the iron. The same change takes place if oxide be mixed with a considerable excess of sulphuric acid, and diluted with water. Common writing ink is a combination of gallat of iron and tannat of iron. If the infusion of nutgalls, which is a compound of tan and gallic acid, be digested upon iron, they dissolve it and form a very good ink. This is the process which Proust considers as the best of all.

Action of heat on it.

When tan is distilled, it yields an acid liquor, which blackens solutions of iron, because it contains a little tan unaltered: there comes over also a little empyreumatic oil, and a voluminous coal remains behind, amounting to $\frac{1}{18}$ of the tan distilled *.

Plants containing it.

Tan exists in almost all those vegetable substances which have an astringent taste. It is almost constantly combined with gallic acid. The following Table, drawn up by Mr Biggin †, from the quantity of precipitate obtained by dropping a solution of glue into the infusion of the plant in water, will serve to give some idea of the proportions of tan which exist in different plants:

	Prop. of Tan.		Prop. of Tan.
Elm	2.1	Sallow	4.6
Oak cut in winter	2.1	Mountain ash	4.7
Horse chesnut	2.2	Poplar	6.0
Beech	2.4	Hazel	6.3
Willow (boughs)	2.4	Ash	6.6
Elder	3.0	Spanish chesnut	9.0
Plum tree	4.0	Smooth oak	9.2
Willow (trunk)	4.0	Oak cut in spring	9.6
Sycamore	4.1	Huntingdon or Leicester willow	10.1
Birch	4.1		
Cherry tree	4.2	Sumach	16.2

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* Proust, *Ann. de Chim.* xxxv. 35.

† *Phil. Trans.* 1799.

SECT. VIII.

OF ACIDS.

The acids found ready formed in vegetables are the following:

1. Acetous,	5. Malic,
2. Oxalic,	6. Gallic,
3. Tartarous,	7. Benzoic,
4. Citric,	8. Phosphoric.

Sometimes also the sulphuric, nitric, and muriatic acids occur in vegetables, combined with alkalies or earths, but never except in very minute quantities.

Acetous acid.

1. Acetous acid is easily detected by its peculiar odour, and by the compounds which it forms with the alkalies and earths. It has been found by Vauquelin in the sap of different trees which he examined, and likewise in the acid juice of the cicer arietinum, which consists of oxalic acid, malic acid, and a little acetous *.

Oxalic.

2. Oxalic acid is easily detected and distinguished by the following properties: It decomposes all calcareous salts, and forms with lime a salt insoluble in water. It readily crystallizes. Its crystals are quadrilateral prisms. It is totally destroyed by heat.

Plants containing it.

Oxalic acid was first detected in vegetables by Scheele. It exists in the state of super-oxalat of potass in the leaves of the *oxalis acetosella*, *oxalis corniculata*, and different species of *rumex*; and likewise in the *geranium*

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* *Jour. de Phys.* lii. 362.

Book IV.

acidum. In the root of *rhubarb* Scheele found it in the state of oxalat of lime, and Deyeux, Dispan, and Vauquelin, have observed it uncombined in the liquid, which exudes from the *cicer parietinum*.

Tartarous.

3. Tartarous acid is known by the following properties: When a little potass is cautiously dropt into a solution containing it, common tartar is formed, and precipitates to the bottom. Tartarous acid does not decompose the sulphat, nitrat, or muriat of lime. Tartrite of lime is soluble in water. Tartarous acid crystallizes. Its crystals are long slender prisms. It is destroyed by heat.

Plants containing it.

Tartarous acid has been found in the following vegetable substances:

The pulp of the tamarind [*].
The juice of grapes.
Mulberries [†]
Rumex acetosa, *sorrel* [†].
Rhus coriaria, *sumach* [†].
Rheum rhaponticum [||].
Agave Americana [¶].
The roots of triticum ripens [†].
Leontodon taraxicum [†].

In the greater number of these it is in the state of supertartrite of potass.

Citric.

4. Citric acid is distinguished by the following properties: It does not form tartar when potass is added to it. With lime it forms a salt insoluble in water, which is decomposed by sulphuric, nitric, and muriatic acids. It readily crystallizes. It is destroyed by heat.

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[*] Vauquelin, *Ann. de Chim.* v. 92.

[†] Hermstadt, on *Veget. Acids.*

[||] Bindheim, Crell, 1788, St. 7. s. 42.

[¶] Hoffman of Weimar.

Plants containing it.

Citric acid has been found unmixed with other acids in the following vegetable substances *:

The juice of oranges and lemons.
The berries of vaccinium oxycoccos, *cranberry*.
——— vitis idæa, *red whortle berry*.
Prunus padus, *birdcherry*.
Solanum dulcamara, *nightshade*.
Rosa canina, *hip*.

It occurs mixed with other acids in many other fruits.

Malic.

5. Malic acid is known by the following properties: It forms with lime a salt soluble in water, which is decomposed by citric acid. It does not form tartar with potass. It is incrystallizable. Heat destroys it.

Plants containing it.

Malic acid has been found by Scheele † in the fruits of the following plants, which contain no other acid:

Apples.
Berberis vulgaris, *barberry*.
Prunus domestica, *plum*.
——— spinosa, *sloe*.
Sambucus nigra, *elder*.
Sorbus aucuparia, *roan* or *service*.

Plants containing citric and malic acids.

In the following fruits he found nearly an equal quantity of malic and citric acids ‡.

Ribes grossularia, *gooseberry*.
——— rubrum, *currants*.
Vaccinium myrtillus, *bleaberry*.
Crategus aria, *beam*.
Prunus cerasus, *cherry*.
Fragaria vesca, *strawberry*.
Rubus chamæmorus, *cloudberries*, *evrochs*.
——— idæus, *raspberry*.

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[*] Scheele, Crell's *Jour.* ii. 8. Eng. Transl.

[†] Ibid.

[‡] Ibid.

Malic acid has also been found in the agave americana [*], and in the pulp of tamarinds [†]. In the first of these it is mixed with tartarous acid; in the second with tartarous and citric acids. Vauquelin has lately detected it in the state of malat of lime, in the following plants:

Sempervivum tectorum.
Sedum album, acre, telephium.
Arum maculatum.
Different species of crassula and mesembrianthemum [‡].

Gallic.

6. Gallic acid is known by the following properties: With the red oxide of iron it produces a black colour. It is crystallizable. Heat destroys it. It has been found in a great number of plants, chiefly in the bark.—The following TABLE, drawn up by Mr Biggin [§], will serve to shew the relative proportions of this acid in different plants:

Plants containing it.

Elm	7	Sallow	8
Oak cut in winter	8	Mountain ash	8
Horse chesnut	6	Poplar	8
Beech	7	Hazel	9
Willow (boughs)	8	Ash	10
Elder	4	Spanish chesnut	10
Plum tree	8	Smooth oak	10
Willow (trunk)	9	Oak cut in spring	10
Sycamore	6	Huntingdon or Leicester willow	10
Birch	4		
Cherry tree	8	Sumach	14

Benzoic.

7. Benzoic acid is distinguished by its aromatic odour, and its volatility on the application of a very moderate

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[*] Hoffman of Weimar.
[†] Vauquelin, *Ann. de Chim.* v. 92.
[‡] *Ann. de Chim.* xxxv. 153.
[§] Nicholson's *Journal*, iii. 394.

Where found.

heat. It has been found hitherto only in a few vegetable substances, to which the French chemists have confined the term *balsam*. These are, *benzoin*, *balsam of tolu*, and *storax*. In these substances it seems to be combined with a resin, or something which has nearly the properties of a resin.

Phosphoric.

8. Phosphoric acid is easily distinguished from the former seven; for it is very fixed, and a violent heat does not destroy it as it does the others.

Phosphoric acid has been found in different plants, but only in very small quantities; it is almost constantly combined with lime. Meyer found it in the leaves of many trees*; Thuren found phosphat of lime in the Aconitus Napellus†; and Bergman found it in all kinds of grain‡.

SECT. IX.

OF ALKALIES.

THE only alkalies found in plants are potass and soda. Ammonia may indeed be obtained by distilling many vegetable substances, but it is produced during the operation. One or other of these alkalies is found in every plant which has hitherto been examined. The quantity indeed is usually very small. From the experiments of Vauquelin it is probable that the alkalies are combined in plants with acetous and carbonic acids.

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* *Encyc. Meth. Physiol. Veget.* i. 100. † *Ann. de Chim.* ii. 308.
‡ Bergman, v. 96.

Potass.

1. Potass is found in almost all plants which grow at a distance from the sea. It may be extracted by burning the vegetable, washing the ashes in water, filtrating the water, and evaporating it to dryness. It is in this manner that all the potash of commerce is procured.

Proportion contained in plants.

The following TABLE exhibits the quantity of ashes and potass which may be extracted from 100 parts of various plants :

	Ashes.	Potass.
Sallow	2.8	0.285† [*]
Elm	2.36727	0.39†
Oak	1.35185	0.15343
Poplar	1.23476	0.07481
Hornbeam	1.1283	0.1254
Beech	0.58432	0.14572
Fir	0.34133	
Vine branches	3.379	0.55†
Common nettle	10.67186	2.5033
Common thistle	4.04265	0.53734
Fern	5.00781	0.6259
Cow thistle	10.5	1.96603
Great river rush	3.85395	0.72234
Feathered rush	4.33593	0.50811
Stalks of turkey wheat	8.86	1.75†
Wormwood	9.744	7.3†
Fumitory	21.9	7.9†
Trifolium pratense		0.078†
Vetches		2.75†
Beans with their stalks		2.0†

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[*] Those marked † are from Kirwan, *Irish Trans*, v. 164. The rest from Pertuis, *Ann. de Chim.* xix. 178.

In general, three times as much ashes are obtained from shrubs, and five times as much from herbs as from trees. Equal weights of the branches of trees produce more ashes than the trunk, and the leaves more than the branches. Herbs arrived at maturity produce more ashes than at any other time. Green vegetables produce more ashes than dry*.

The salt which is obtained from plants does not consist wholly of potass, there are other salts mixed with it; these usually are sulphat of potass, muriat of potass, sulphat of lime, phosphat of lime, &c; but these bear, in general, but a small proportion to the potass. The ashes consist of potass mixed with earths.

Some judgment may be formed of the quantity of potass which a plant contains from the quantity of ashes which it yields: but the above Table is sufficient to shew us, that were we to trust to that we would often be misled.

Soda.

2. Soda is found in almost all the plants which grow in the sea, and in many of those which grow on the shore. In general, the quantity of soda which plants contain bears a much greater proportion to their weight than the potass does which is found in inland vegetables. 100 parts of the *salsola soda*, for instance, yield 19.921 of ashes; and these contain 1.992 parts of soda; some of which, however, is combined with muriatic acid †. The plants from which the greater part of the soda, or *barilha*, as it is called, which is imported from Spain, is extracted, are the *salsola sativa* and *vermiculata*.

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* *Ann. de Chim.* xix. 174.

† Vauquelin, Ibid. xviii. 77.

SECT. X.

OF OILS.

There are two species of oils; namely, *fixed* and *volatile;* both of which are found abundantly in plants.

Fixed oil, where found.

1. Fixed oil is only found in the seeds of plants, and is almost entirely confined to those which have two cotyledons; as lintseed, almonds, beech root, poppy seed, rape seed, &c. Sometimes, though rarely, it is found in the pulp which surrounds the stone of certain fruits. This is the case with the olive, which yields the most abundant and most valuable species of fixed oil. The bicotyledinous seeds, besides oil, contain also a mucilaginous substance; and they have all the character of forming, when bruised in water, a milky liquid, known by the name of *emulsion.*

Volatile oil, where found.

2. Volatile oils are found in every part of plants except the cotyledons of the seeds, where they never occur. The root, the stem, the leaves, the flower, the rind or pulp of the fruit of a variety of plants, are loaded with volatile oils, from which they are extracted by expression or by distillation. The number of these oils is so great that it baffles all description. Every plant which is distinguished by a peculiar odour contains a volatile oil to which it is indebted for that odour.

SECT. XI.

WAX AND TALLOW.

Wax a vegetable production.

THE upper surface of the leaves of many trees is covered with a varnish, which may be separated and obtained in a state of purity by the following process.

Digest the bruised leaves, first in water and then in alcohol, till every part of them which is soluble in these liquids be extracted. Then mix the residuum with six times its weight of a solution of pure ammonia, and, after sufficient maceration, decant off the solution, filter it, and drop into it, while it is incessantly stirred, diluted sulphuric acid, till more be added than is sufficient to saturate the alkali. The varnish precipitates in the form of a yellow powder. It should be carefully washed with water, and then melted over a gentle fire *.

Mr Tingry first discovered that this varnish possessed all the properties of *bees wax* †. Wax, then, is a vegetable product. The bees extract it unaltered from the leaves of trees and other vegetable substances which contain it. They seem, however, to mix it with some of the pollen of flowers.

Its properties.

Wax, when pure, is of a whitish colour, it is destitute of taste, and has scarcely any smell. Bees wax indeed has a pretty strong aromatic smell ; but this seems chiefly owing to some substance with which it is mix-

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* Hermstadt, *Med. and Phys. Jour.* iii. 372.

† *Enc. Meth. Forets et Bois*, i. 100.

ed; for it disappears almost completely by exposing the wax, drawn out into thin ribands, for some time to the atmosphere. By this process, which is called *bleaching*, the yellow colour of the wax disappears, and it becomes very white. Bleached wax is not affected by the air [*].

Action of alkakies.

Wax is insoluble in water and in alcohol. It combines readily with alkalies, and forms with them a soap which is soluble in water, and possesses the properties of common soap. Punic wax, which the ancients employed in painting in encausto, is a soap composed of twenty parts of wax and one of soda [†]. Its composition was ascertained by Mr Lorgna [‡].

Of acids.

The acids have but little action on wax; even oxymuriatic acid, which acts so violently on most bodies, produces no other change on it than that of rendering it white. This property which wax possesses, of resisting the action of acids, renders it very useful as a lute to confine acids properly in vessels, or to prevent them from injuring a common cork.

Of oils.

Wax combines readily with oils, and forms with them a substance of greater or less consistency according to the quantity of oil. This composition, which is known by the name of *cerate*, is much employed by surgeons.

Of heat.

When heat is applied to wax it becomes soft; and at the temperature of 142°, if unbleached, or of 155° if bleached [§], it melts into a colourless transparent fluid, which concretes again, and resumes its former

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[*] Senebier, *Ann. de Chim.* xii. 60. and *Jour. de Phys.* xxxviii. 56.

[†] Pliny, lib. xxi. c. 14.

[‡] *Jour. de Phys.* Nov. 1785.

[§] Nicholson's *Journal*, i. 71.

appearance as the temperature diminishes. If the heat be still farther increased, the wax boils and evaporates; and if a red heat be applied to the vapour, it takes fire and burns with a bright flame. It is this property which renders wax so useful for making candles.

Its composition.

Mr Lavoisier, by means of the apparatus which he employed in the analysis of alcohol and oils, and which has been described in the First Part of this Work, contrived to burn wax in oxygen gas. The quantity of wax consumed was 21.9 grains. The oxygen gas employed in consuming that quantity amounted to 66.55 grains. Consequently the substances consumed amounted to 88.45 grains. After the combustion, there were found in the glass vessel 62.58 grains of carbonic acid, and a quantity of water, which was supposed to amount to 25.87 grains. These were the only products.

Now 62.58 grains of carbonic acid gas contain

44.56 of oxygen and 18.02 of carbon; and 25.87 gr. of water contain
21.99 of oxygen and 3.88 of hydrogen

66.55 21.90

Consequently 21.9 parts of wax are composed of 18.02 of carbon and 3.88 of hydrogen. And 100 parts of wax are composed of 82.28 carbon
17.72 hydrogen

100.00*

But this analysis can only be considered as an approximation to the truth; the quantity of water being only estimated, and that of the gas being liable to uncertainty. There can be no doubt, from the little action of acids on wax, that it contains oxygen as an in-

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* Lavoisier, *Jour. de Phys.* xxxi. 59.

gredient. We must therefore consider it as a triple compound of carbon, hydrogen, and oxygen; but the proportions are unknown.

Distillation.

If wax be distilled with a heat greater than 212°, there comes over a little water, some sebacic acid, a little very fluid and odorous oil: the oil, as the distillation advances, becomes thicker and thicker, till at last it is of the consistency of butter, and for this reason has been called *butter of wax*. There remains in the retort a small quantity of coal, which is not easily reduced to ashes. When the butter of wax is repeatedly distilled, it becomes very fluid, and assumes the properties of volatile oil *.

Formation from oil.

Wax possesses all the essential properties of fixed oil. We must therefore consider it as a fixed oil rendered concrete. Now that species of fixed oils, distinguished by the epithet *fat*, have the property of becoming concrete, and assuming the appearance of wax when exposed long to the air; in consequence, it is supposed, of the absorption of oxygen. Hence probably the difference between wax and fixed oils consists in the oxygen which it contains as a component part. The wax at its first formation was in all probability in the state of a fixed oil; but by the absorption of oxygen it gradually concreted into wax.

Butter and tallow.

It is natural to suppose, if this theory be just, that fixed oil will occur in plants in various states of hardness; and this accordingly is the case. Sometimes it is of the consistency of butter, and this is denominated a *butter*; thus we have the butter of *cacao*, the butter of *coco*, the butter of *galam*. Sometimes it is of a great-

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* Lemery, *Mem. Par.* 1708, p. 53.

er consistency, and then is denominated *tallow;* thus we have the tallow of the *croton,* extracted by boiling water from the fruit of the *croton sebifere.* When its consistency is as great as possible, it then takes the appellation of *wax.* Thus we have the *green wax* of America, the wax extracted from the seeds of the *myrica cerifera,* and the *pela* of the Chinese. All these substances agree in their properties with bees wax, except in their consistency and their colour. They are usually extracted from the plants that contain them by maceration in boiling water. The wax melts and swims on the surface. In China this vegetable wax is employed in the manufacture of candles, and applied to all the other uses to which bees wax is subservient.

Plants where found.

SECT. XII.

OF RESIN.

THERE is a yellowish white coloured subſtance which often exudes from the *Abies Montana,* or *common Scotch fir,* and likewise from other fir trees. It is somewhat transparent, is hard and brittle, of a disagreeable taste, and may be collected in considerable quantities. This substance is known by the name of *resin;* and the same name is also applied to all substances which possess nearly the same properties with it. Resin may be distinguished from every other substance by the following properties.

Origin.

It is more or less concrete, and possesses a certain degree of transparency. Its taste is sometimes hot and

Properties.

disagreeable, but not unfrequently it is tasteless, or nearly so. Its colour varies, but it is most frequently between yellow and brown. Its specific gravity varies from 1.0452 to 1.2289. It is a non-conductor of electricity, and of course an electric.

Action of heat,

When resin is heated it readily melts; and if the heat be increased it is volatilized, and burns with a white flame and strong smell, emitting a great quantity of smoke. When distilled it yields much volatile oil, but scarcely any acid.

Of water,

It is totally insoluble in water. By this property it may easily be separated from gum, if they happen to be mixed together.

Of alcohol,

It is soluble in alcohol, and in sulphuric ether *. By the first of these properties we may separate it from gum, and by the last from extract; for extract is insoluble in sulphuric ether. When these solutions are evaporated, the resin is obtained unaltered. If the solution be spread thin upon any body, it soon dries by the evaporation of the alcohol; the resin remains behind, and covers the body with a smooth shining transparent coat, which cannot be washed off by water. This process is called *varnishing*.

Of oils,

Resin is soluble also in volatile oils; and these solutions are often used likewise in varnishing.

Of acids and alkalies.

Resin is scarcely acted upon by acids or alkalies. It combines with sulphur by fusion, and likewise with phosphorus.

Formation.

When volatile oils are exposed for some time to the action of the atmosphere they acquire consistency, and assume the properties of resins. During this change

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* Hermstadt.

they absorb a quantity of oxygen from the air. Westrum put 30 grains of oil of turpentine into 40 cubic inches of oxy-muriatic acid gas. Heat was evolved, the oil gradually evaporated, and assumed the form of yellow resin *. Mr Proust observed, that when volatile oil is exposed to the air, it is partly converted into a resin, and partly into a crystallized acid; usually the benzoic or the camphoric. Hence we see that the oil is converted into two distinct substances. During this change oxygen is absorbed; and Fourcroy has observed that a portion of water is also formed †. It is probable, from these facts, that resin is volatile oil deprived of a portion of its hydrogen, and combined with oxygen. Resin, therefore, is to volatile oil what wax is to fixed oil; and doubtless owes its formation to the changes which the volatile oils of vegetables undergo.

Plants containing it.

To know whether any vegetable substance contains resin, we have only to pour some sulphuric ether upon it in powder, and expose the infusion to the light. If any resin be present the ether will assume a brown colour ‡.

Resin is contained in a great variety of plants. Sometimes it exudes and concretes upon the surface of the plant; sometimes it flows out in considerable quantity when the plant is wounded; but very often it remains mixed with the vegetable fibres, from which it may be extracted by alcohol, and afterwards purified from extract by water.

The number of resins is immense, as there is scarce a single plant which is destitute of them. They differ from each other chiefly in colour, taste, smell, and con-

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* Crell's *Annals*, i. 1790. † Fourcroy, viii. 16. ‡ Hermstadt.

sistency. Whether these resins be really different combinations, or owe these differences to foreign ingredients, either combined with the resin, or mechanically mixed with it, is not at present known. To describe each resin separately would be to little purpose, as scarcely any thing is known of them except their general properties as resins. The following are the most important:

List of resins.

1. Turpentine of Chio, which exudes from the *pistacea terebinthus.*

2. Venice turpentine, which is usually employed in medicine.

3. Strasburgh turpentine, from the common fir. From which also are procured *barras* and *tar.*

4. Pitch, from the *pinus picea.*
5. Elemi, from the *amyris elemifera.*
6. Mastic, from the *pistacea lentiscus.*
7. Sandarac, employed usually as a varnish.
8. Guayac, from the *guayacum officinale.*
9. Ladanum, from the *cistus ladaniferus.*
10. Dragon's blood, from the *dracæna draco.*
11. Balsam of Mecca, from the *amyris opobasamum.*
12. Balsam of Copahu, from the *Copacfera officinalis.*

Balsams.

Resins sometimes occur combined with benzoic acid. This compound was denominated *balsam* by Bucquet in 1774, and the term has since been adopted by chemists to denote a compound of benzoic acid and resin. The balsams at present known are:

1. Benzoin, from the *styrax benzoin.*
2. Balsam of Tolu, from the *toluifera balsamum.*
3. Balsam of Peru, from the *myroxylon peruiferum.*
5. Storax, from the *styrax officinalis.*

There is another set of bodies much used in medicine, and distinguished by the name of *gum resins*, because they are partly soluble both in water and alcohol. These bodies are obtained by making incisions into the plants containing them ; a juice flows out, which concretes into a solid body, and is then called a gum resin. Hence it is evident that they consist of a variety of substances combined together. All the substances must be present in them which constituted a part of the juices of the plant. To attempt a description of them would be vain ; and as they have not hitherto attracted the attention of chemists, we are ignorant of their component parts. They have all a strong disagreeable taste, and several of them a very strong smell, resembling that of garlic. They act very powerfully as medicines. The most important of them are the following :

1. Olibanum, from the *juniperus lycia.*
2. Galbanum, from the *bubon galbanum.*
3. Scammony, from the *convolvulus scammonia.*
4. Assa fœtida, from the *ferula assa fœtida.*
5. Myrrh, } the plant not ascertained.
6. Ammoniac, } the plant not ascertained.
7. Aloes, from the *aloe perfoliata.*
8. Opium, from the *papaver somniferum.*

SECT. XIII.

OF CAMPHOR.

Extraction.

The laurus camphorata is a tree which grows in China, Japan, and several parts of India. When the roots of this tree are put into an iron pot furnished with a capital, and a sufficient heat is applied, a particular substance sublimes into the capital, which is known by the name of *camphor*. The Dutch afterwards purify this camphor by a second sublimation.

Properties.

Camphor is a white brittle substance, having a peculiar aromatic odour and a strong hot acrid taste. Its specific gravity is 0.9887.

It is not altered by atmospheric air; but it is so volatile, that if it be exposed during warm weather in an open vessel, it evaporates completely. When sublimed in close vessels it crystallizes in hexagonal plates or pyramids *.

Action of water,

It is insoluble in water; but it communicates to that liquid a certain portion of its peculiar odour.

Alcohol,

It dissolves readily in alcohol, and is precipitated again by water. If the alcohol be diluted with water as much as possible, without causing the camphor to precipitate, small crystals of camphor resembling feathers gradually form †.

Oils.

Camphor is soluble also in hot oils, both fixed and volatile; but as the solution cools, the camphor precipitates, and assumes the form of plumose, or feather-like crystals ‡.

Alkakies,

Camphor is not acted on by alkalies, either pure or in the state of carbonats. Pure alkalies indeed seem to dissolve a little camphor; but the quantity is too small to be perceptible by any other quality than its odour §. Neither is it acted upon by any of the neutral salts which have hitherto been tried.

Acids.

Acids dissolve camphor, but it is precipitated again,

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* Romieu.

† Romieu, *Mem. Par.* 1756. p. 41.

‡ Ibid.

§ Bouillon la Grange, *Ann. de Chim.* xxiii. 154.

unaltered, by alkalies, and even by water. The solution of camphor in sulphuric acid is red; that in the nitric acid is yellow. This last solution has obtained the absurd name of *oil of camphor*. When nitric acid is distilled repeatedly off camphor, it converts it into camphoric acid.

Muriatic, sulphurous, and fluoric acids, in the state of gas, dissolve camphor. When water is added, the camphor appears unaltered in flakes, which swim on the surface of the water *. It is dissolved also by water impregnated with carbonic acid gas †.

Action of heat.

When heat is applied to camphor it is volatilized. If the heat be sudden and strong, the camphor melts before it evaporates; and it melts, according to Venturi, at the temperature of 300°. It catches flame very readily, and emits a great deal of smoke as it burns, but it leaves no residuum. It is so inflammable that it continues to burn even on the surface of water. When camphor is set on fire in a large glass globe filled with oxygen gas, and containing a little water, it burns with a very bright flame, and produces a great deal of heat. The inner surface of the glass is soon covered with a black powder, which has all the properties of charcoal, a quantity of carbonic acid gas is evolved, the water in the globe acquires a strong smell, and is impregnated with carbonic acid and camphoric acid ‡.

If two parts of alumina and one of camphor be formed into a paste with water, and distilled in a glass retort, there comes over into the receiver (which should contain a little water and communicate with a pneu-

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* Fourcroy. † *Jour. de Phys.* lii. 67.

‡ Bouillon la Grange, *Ann. de Chim.* xxiii. 168.

matic apparatus) a volatile oil of a golden yellow colour, a little camphoric acid which dissolves in the water, and a quantity of carbonic acid gas and carbonate hydrogen gas, which may be collected by means of pneumatic apparatus. There remains in the retort a substance of a deep black colour, composed of alumin and charcoal. By this process, from 122.284 parts o camphor, Mr Bouillon la Grange, to whom we are indebted for the whole of the analysis of camphor, obtained 45.856 parts of volatile oil, and 30.571 parts o charcoal. The proportion of the other products wa not ascertained *.

Composition.

From this analysis, Mr Bouillon la Grange conclude that camphor is composed of volatile oil and charco or carbon combined together. We learn, from his experiments, that the ultimate ingredients of camphor ar carbon and hydrogen; and that the proportion of carbon is much greater than in oils.

Plants containing it.

Camphor exists in a great many plants. Neumann Geoffroy, and Cartheuser, extracted it from the root of zedoary, thyme, sage, &c. and rendered it probabl that it is contained in almost all the labiated plant It has been supposed to exist in these plants combine with volatile oil. Proust has shewn how it may be extracted, in considerable quantity, from many volati oils †. All that is necessary, is to expose the oil to th open air at a temperature between 22° and 54°; th oil gradually evaporates, and the camphhor crystallize By this process he obtained from the oil of rosemar $\frac{1}{10}$ of its weight of camphor, from that of sweet ma

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* Bouillon la Grange, *Ann. de Chim.* xxiii. 157.

† *Ann de Chim.* iv. 179.

joram $\frac{1}{10}$, from oil of sage $\frac{1}{8}$, and from oil of lavender more than $\frac{1}{4}$th. By distilling the oil in a water-bath, some degrees under the boiling point, till one-third of the oil comes over, part of the camphor is found crystallized in the still vessel. This being removed, and the oil again distilled as before, more camphor crystallizes. By three such processes the whole of the camphor is obtained from the oil. The camphor is then purified by mixing it with a little dry lime, and subliming it.

Camphor, which was unknown to the ancient Greeks and Romans, was introduced into Europe by the Arabians. Ætius was the first person who mentions it. It seems, however, to have been very early known to the eastern nations.

It is much used in medicine. It is a powerful stimulant; it is considered as peculiarly efficacious in diseases of the urinary organs; it is often serviceable in mania, and procures sleep when every other medicine fails.

SECT. XIV.

OF GLUTEN.

Extraction.

If wheat flour be knedded into a paste with a little water, it forms a tenacious, elastic, soft ductile, mass. This is to be washed cautiously, by knedding it under a small jet of water till the water no longer carries off any thing, but runs off colourless; what remains behind is called *gluten*. It was discovered by Beccaria, an Italian philosopher, to whom we are indebted for the first analysis of wheat flour *.

Properties.

Gluten, when thus obtained, is of a grey colour, exceedingly tenacious, ductile, and elastic, and may be extended to twenty times its original length. When very thin, it is of a whitish colour, and has a good deal of resemblance to animal tendon or membrane. In this state it adheres very tenaciously to other bodies, and has often been used to cement together broken pieces of porcelain. Its smell is peculiar. It has scarce any taste, and does not lose its tenacity in the mouth. When exposed to the air it assumes a brown colour, and becomes as it were covered with a coat of oil.

When exposed to the air, it gradually dries; and when completely dry, it is pretty hard, brittle, slightly transparent, of a dark brown colour, and has some resemblance to *glue*. It breaks like a piece of glass, and the edges of the fracture resemble in smoothness those of broken glass; that is to say, it breaks with a *vitreous* fracture.

When exposed to the air, and kept moist, it soon putrefies; but when dry, it may be kept any length of time without alteration. When not entirely deprived of starch, instead of putrefying, it assumes the appearance and taste of cheese †.

Action of water,

It is insoluble in water; though it imbibes and retains a certain quantity of it with great obstinacy. To this water it owes its elasticity and tenacity. When boiled in water it loses both these properties.

Acids,

All the acids dissolve it, even when very much diluted; alkalies precipitate it again, but it is deprived of it

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* *Collect. Academ.* x. i.

† Rouelle.

elasticity, and in a state which Macquer considered as approaching that of mucilage. Concentrated sulphuric acid renders it violet coloured, and at last black; inflammable air escapes, and charcoal, water, and a portion of ammonia, are formed *. When nitric acid is poured on it, and heat applied, there is a quantity of azotic gas emitted, as Berthollet discovered; and by continuing the heat, a quantity of oxalic acid is formed †, and likewise malic acid, while a number of yellow-coloured oily flakes make their appearance in the solution.

Alkalies.

Alkalies dissolve gluten when they are assisted by heat. The solution is never perfectly transparent. Acids precipitate the gluten from alkalies, but it is destitute of its elasticity ‡. Alkalies, when much concentrated, form with it a kind of soap, converting it into oil and ammonia; which last is dissipated during the trituration.

Action of heat.

When moist gluten is suddenly dried, it swells amazingly. Dry gluten, when exposed to heat, cracks, swells, melts, blackens, exhales a fetid odour, and burns precisely like feathers or horn. When distilled, there comes over water impregnated with ammonia and an empyreumatic oil; the charcoal which remains is with difficulty reduced to ashes. From these phenomena, it is evident that gluten is composed of carbon, hydrogen, azot, and oxygen: perhaps also it contains a little lime. In what manner these substances are combined is unknown.

Composition.

Plants containing it.

The only vegetable substance from which it has been hitherto extracted is wheat fluor; but it seems to ex-

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* Fourcroy, vii. 304.

† Vauquelin, *Ann. de Chim.* vi. 278.

‡ Fourcroy.

ist, though in a very small proportion, in several of the other species of corn.

SECT. XV.

OF CAOUTCHOUC.

History.

ABOUT the beginning of the 18th century, a substance called *caoutchouc* was brought as a curiosity from America. It was soft, wonderfully elastic, and very combustible. The pieces of it that came to Europe were usually in the shape of bottles, birds, &c. This substance is very much used in rubbing out the marks made upon paper by a black lead pencil; and therefore in this country it is often called *Indian rubber*. Nothing was known of its production, except that it was obtained from a tree, till the French academicians went to South America in 1735 to measure a degree of the meridian. Mr de la Condamine sent an account of it to the French Academy in the year 1736. He told them, that there grew in the province of Esmeraldas, in Brazil, a tree, called by the natives *Hhevé*; that from this tree there flowed a milky juice, which, when inspissated, was *caoutchouc*. Don Pedro Maldonado, who accompanied the French academicians, found the same tree on the banks of the Maragnon; but he died soon after, and his papers were never published. Mr Fresnau, after a very laborious search, discovered the same tree in Cayenne. His account of it was read to the French Academy in 1751.

Chap. I.

Plants containing it.

It is now known that there are at least two trees in South America from which caoutchouc may be obtained; the Hævea Caoutchouc and the Jatropha Elastica; and it is exceedingly probable that it is extracted also from other species of Hævea and Jatropha. Several trees likewise which grow in the East Indies yield caoutchouc; the principal of these are, the Ficus Indica, the Artocarpus Integrifolia, and the Urceola Elastica, a plant discovered by Mr Howison, and first described and named by Dr Roxburgh [*].

When any of these plants is punctured, there exudes from it a milky juice, which, when exposed to the air, gradually lets fall a concrete substance, which is caoutchouc.

If oxy-muriatic acid be poured into the milky juice, the caoutchouc precipitates immediately, and, at the same time, the acid loses its peculiar odour. This renders it probable that the formation of the caoutchouc is owing to its basis absorbing oxygen [†]. If the milky juice be confined in a glass vessel containing common air, it gradually absorbs oxygen, and a pellicle of caoutchouc appears on its surface [‡].

Caoutchouc was no sooner known than it drew the attention of philosophers. Its singular properties promised that it would be exceedingly useful in the arts, provided any method could be fallen upon to mould it into the various instruments for which it seemed peculiarly adapted. Messrs de la Condamine and Fresnau had mentioned some of its properties; but Macquer was the first person who undertook to examine it with

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[*] *Asiatic Researches*, v. 167. London Edition.

[†] Fourcroy, *Ann. de Chim.* xi. 229.

[‡] Ibid.

attention. His experiments were published in the Memoirs of the French Academy for the year 1768. They threw a good deal of light on the subject; but Macquer fell inso some mistakes, which were pointed out by Mr Berniard who published an admirable paper on caoutchouc in the 17th volume of the *Journal de Physique*. To this paper we are indebted for the greater number of facts at present known respecting caoutchouc. Mr Grossart and Mr Fourcroy have likewise added considerably to our knowledge of this singular substance; both of their Treatises have been published in the 11th volume of the *Annales de Chimie*.

Properties.

Caoutchouc, when pure, is of a white colour *, and without either taste or smell. The blackish colour of the caoutchouc of commerce is owing to the method employed in drying it after it has been spread upon moulds. The usual way is to spread a thin coat of the milky juice upon the mould, and then to dry it by exposing it to smoke; afterwards another coat is spread on, which is dried in the same way. Thus the caoutchouc of commerce consists of numerous layers of pure caoutchouc alternating with as many layers of soot.

Caoutchouc is soft and pliable like leather. It is exceedingly elastic and adhesive; so that it may be forcibly stretched out much beyond its usual length, and instantly recover its former bulk when the force is withdrawn. It cannot be broken without very considerable force. Its specific gravity is 0.9335 †.

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* I have seen some pieces of it from the East Indies, which had been allowed to inspissate in the open air: They were white, with a slight cast of yellow, and had very much the appearance and feel of white soap.

† Fourcroy, viii. 39.

Action of water,

It is not altered by exposure to the air; it is perfectly insoluble in water: but if boiled for some time its edges become somewhat transparent, owing undoubtedly to the water carrying off the soot; and so soft, that when two of them are pressed and kept together for some time, they adhere as closely as if they formed one piece. By this contrivance pieces of caoutchouc may be soldered together, and thus made to assume whatever shape we please*.

Alcohol,

Caoutchouc is insoluble in alcohol. This property was discovered very early, and fully confirmed by the experiments of Mr Macquer. The alcohol, however, renders it colourless.

Ether,

Caoutchouc is soluble in ether. This property was first pointed out by Macquer. Berniard, on the contrary, found that caoutchouc was scarcely soluble at all in sulphuric ether, which was the ether used by Macquer, and that even nitric ether was but an imperfect solvent. The difference in the results of these two chemists was very singular; both were remarkable for their accuracy, and both were too well acquainted with the subject to be easily misled. The matter was first cleared up by Mr Cavallo. He found that ether, when newly prepared, seldom or never dissolved caoutchouc completely; but if the precaution was taken to wash the ether previously in water, it afterwards dissolved caoutchouc with facility. Mr Grossart tried this experiment, and found it accurate†. It is evident from this that these chemists had employed ether in different states. The washing of ether has two effects. It deprives it of a little acid with which it is often impreg-

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* Grossart, *Ann. de Chim.* xi. 153.

† Ibid. p. 147.

nated, and it adds to it about one-tenth of water, which remains combined with it.

When the ether is evaporated, the caoutchouc is obtained unaltered. Caoutchouc, therefore, dissolved in ether, may be employed to make instruments of different kinds, just as the milky juice of the hævea; but this method would be a great deal too expensive for common use.

Volatile oils,

Caoutchouc is soluble in volatile oils *: but, in general, when these oils are evaporated, it remains somewhat glutinous, and therefore is scarcely proper for those uses to which, before its solution, it was so admirably adapted.

Alkalies and acids,

It is insoluble in alkalies †. The acids act upon it with more or less violence according to their nature. Sulphuric acid decomposes it completely, charcoal precipitates, and part of the acid is converted into sulphurous acid. When treated with nitric acid, there came over azotic gas, carbonic acid gas, prussic acid gas; and oxalic acid was formed ‡. Muriatic acid does not affect it §. The other acids have not been tried.

Petroleum.

Fabroni has discovered, that rectified petroleum dissolves it, and leaves it unaltered when evaporated ||.

Action of heat.

When exposed to heat it readily melts; but it never afterwards recovers its properties, but continues always of the consistence of tar. It burns very readily with a bright white flame, and diffuses a fetid odour. In those countries where it is produced, it is often used by way of candle.

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* Berniard.

† Id.

‡ *Ann. de Chim.* xi. 232.

§ Berniard.

|| *Ann. de Chim.* xi. 195. and xii. 156.

When distilled, it gives out ammonia*. It is evident from this, and from the effect of sulphuric and nitric acid upon it, that it is composed of carbon, hydrogen, azot, and oxygen; but the manner in which they are combined is unknown.

How extracted from plants.

It seems to exist in a great variety of plants; but is usually confounded with the other ingredients. It may be separated from resins by means of alcohol. It may be extracted from the different species of *misletoe* by water, with which, in the fluid state in which it exists in these plants, it readily combines. When mixed with gum or extract, it may be separated by the following process: Digest a part of the plant containing it first in water and then in alcohol, till all the substances soluble in these liquids be extracted. Dry the residuum, and digest it in five times its weight of rectified petroleum. Express the liquid part by squeezing the substance in a linen cloth. Let this liquid remain several days to settle, then decant off the clear liquid part, mix it with a third part of water, and distil, the caoutchouc remains behind†.

According to Bucholz, opium contains a considerable portion of caoutchouc‡. That part of *mastich* which is insoluble in alcohol is said also to be pure caoutchouc§.

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* *Ann. de Chim.* xi. 232.

† Hermstadt, *Med. and Phys. Jour.* iii. 372.

‡ *Ann. de Chim.* xxxiv. 133.

§ *Jour. de Min.* No v. 86.

SECT. XVI.

OF WOOD.

Extraction.

ALL trees, and most other plants, contain a particular substance, well known by the name of *wood*. If a piece of wood be well dried, and digested, first in a sufficient quantity of water, and then of alcohol, to extract from it all the substances soluble in these liquids, there remains behind only the *woody fibre*.

Properties.

This substance, which constitutes the basis of wood, is composed of longitudinal fibres, easily subdivided into a number of smaller fibres. It is somewhat transparent; is perfectly tasteless; has no smell; and is not altered by exposure to the atmosphere.

It is insoluble in water and in alcohol. The fixed alkalies, when assisted by heat, give it a deep brown colour, render it soft, and decompose it.

Action of heat.

When heated, it blackens without melting or frothing up, and exhales a disagreeable acrid fume, and leaves a charcoal which retains exactly the form of the original mass. When distilled in a retort, it yields an acid liquor of a peculiar taste and smell, distinguished by the name of pyrolignous, and formerly considered as a distinct acid; but Fourcroy and Vauquelin have lately ascertained that it is merely the acetous acid combined with an empyreumatic oil.

Action of nitric acid.

By nitric acid Fourcroy converted the residuum of quinquina, which does not seem to differ from the woody fibre, into oxalic acid; at the same time there

was a little citric acid formed, and a very small quantity of malic and acetous acids. Some azotic gas also was disengaged. By this process he obtained from 100 parts of woody fibre 56.250 oxalic acid
3.905 citric acid
0.388 malic acid
0.486 acetous acid
0.867 azotic gas
8.330 carbonat of lime

70.226
32.031 residuum

102.257

There was likewise a quantity of carbonic acid gas disengaged, the weight of which was unknown. This increase of weight in the product was evidently owing to the oxygen derived from the nitric acid†.

When this residuum was distilled in a retort, 100 parts yielded the following products:

26.62 of a yellow liquid, containing alcohol, and an acid which had the smell of pyromucous.
6.977 of concrete oil, mostly soluble in alcohol
22.995 charcoal } in the retort
3.567 carbonat of lime }

60.159
39.841 gas, half carbonic acid, half carbonated hydrogen

100.000†

When wood is burnt with a smothered flame, it leaves,

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* *Ann. de Chim.* viii. 153.

† Ibid. 151.

Leaves a residuum of charcoal.

as is well known, a quantity of charcoal behind it, which exhibits the exact form, and even the different layers of the original wood. As it is the *wood* alone which undergoes this change, while the other component parts of the plant are dissipated, we may form some notion of the relative proportion of wood which different plants contain by the proportion of charcoal which they yield. Now, the quantity of charcoal yielded by 1.00 of different trees is, according to the experiments of Proust, as follows:

Black ash	0.25
Guaiaeum	0.24
Pine	0.20
Green oak	0.20
Heart of oak	0.19
Wild ash	0.17
White ash	0.17

Composition.

Theory of Chaptal.

From the facts above related, it appears that the *wood* of plants is composed of oxygen, carbon, hydrogen, azot, and lime. Mr Chaptal supposes that mucilage differs from woody fibre merely in containing less oxygen. We are certain at least that mucilage or gum is composed of the same ingredients; and Mr Chaptal has shewn, that the juices of plants are partly converted into a substance similar to woody fibre by oxy-muriatic acid, which imparts to them oxygen *. These juices contain both gum and resin: after the formation of the woody fibre the resin is still unaltered. This gives some probability to his opinion, provided it can be proved that extract, by combining with oxygen, assumes the properties of wood; for the precipitate observed by Chaptal was undoubtedly extract.

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* *Ann. de Chim.* xxi. 285.

SECT. XVII.

OF SUBER.

This name has been introduced into chemistry by Fourcroy, to denote the outer bark of the *quercus suber*, or the common cork, a substance which possesses properties different from all other vegetable bodies.

Its properties.

It is exceedingly light, soft, and elastic; very combustible, burning with a bright white flame, and leaving a light black bulky charcoal; and when distilled it yields a little ammonia. Nitric acid gives it a yellow colour, corrodes, disolves, and decomposes it, converting it partly into suberic acid, partly into a substance resembling wax.

Fourcroy supposes, from some experiments which he does not relate, that the epidermis of all trees is a substance possessed of the same properties with cork.

SECT. XVIII.

OF EARTHS.

The only earths hitherto found in plants are the four following; *lime*, *silica*, *magnesia*, *alumina*.

Lime.

1. Lime is usually the most abundant of the earths of plants, and the most generally diffused over the vege-

table kingdom. Indeed it is a very uncommon thing to find a plant entirely destitute of lime: salsola soda i almost the only one in which we know for certain tha this earth does not exist *.

Silica.

2. Silica exists also in many plants, particularly i grasses and equisetums. Mr Davy has ascertained tha it forms a part of the epidermis, or outermost bark o these plants; and that in some of them almost the whol epidermis is silica.

	Parts Silica
100 parts of the epid. of bonnet cane yielded	90
bamboo	71.4
(arundo phragm.) common reed . . .	48.1
stalks of corn	6.5

The concretions which are sometimes found in th bamboo cane have been ascertained by Mr Macie to b composed of pure silica.

Magnesia.

3. Magnesia does nos exist so generally in the vegetable kingdom as the two preceding earths. It has been found, however, in considerable quantities in severa sea plants, especially fuci †. But the salsola soda contains a greater proportion of magnesia than any plan hitherto examined. Mr. Vauquelin found that 100 parts of it contained 17.929 of that earth ‡.

Alumina.

4. Alumina has only been found in very small quantities in plants.

The following TABLE will shew the quantity of these four earths which exist in several vegetables.

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[*] Vauquelin, *Ann. de Chim.* xviii. 76.

[†] Id. Ibid. 86. and ix. 94.

[‡] Ibid. 78.

Chap. I.

Proportion of earths.

100 parts of oak contain of earths	1.03 [*]
Beech	0.453 [†]
Fir	0.003 [†]
Turkey wheat	7.11 [†]
Sunflower	3.72 [†]
Vine branches	2.85 [†]
Box	2.674 [†]
Willow	2.515 [†]
Elm	1.96 [†]
Aspin	1.146 [†]
Fern	3.221 [‡]
Wormwood	2.444 [§]
Fumitory	14.000 [§]

This Table shews us, that the quantity of earth is greater in herbs than in trees.

Bergman found all the four earths in every kind of grain which he analysed [‖].

Vauquelin found, that 100 parts of oat grain left 3.1591 of residuum. This residuum is composed of

60.7	silica
39.3	phosphat of lime
100.0 [¶]	

When the whole of the avena sativa, however, stalk and seed together, is burnt, it leaves a residuum composed of

55	silica
15	phosphat of lime
20	potass
5	carbonat of lime
95	and a little oxide of iron [**].

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[*] Watson.

[†] Kirwan, *Irish Trans.* iii. 35.

[‡] Home.

[§] Wiegleb.

[‖] *Opusc.* v. 94.

[¶] *Ann. de Chim.* xxix. 17.

[**] Ibid. 19.

This shews us that the stalk contains several substances not to be found in the grain.

SECT. XIX.

OF METALS.

SEVERAL metallic substances have also been found in the ashes of vegetables, but their quantity is exceedingly small; so small, indeed, that without very delicate experiments their presence cannot even be detected.

Iron and manganese.

The metals hitherto discovered are iron, which is by far the most common, manganese, and, if we believe some chemists, gold.

Scheele first detected manganese in vegetables [*]. Proust found it in the ashes of the pine, calendula, vine, green oak, and fig-tree [†]. Iron exists in most plants. The ashes of some species of salsola contain a considerable quantity of it. With respect to the minute portion of gold extracted from the ashes of plants by Kunkel, Sage, &c. it is probable that it proceeded rather from the lead which they employed in their processes than from the gold.

THUS we have taken a survey of all the substances which have hitherto been obtained from vegetables: by analysing each of these, we come at last to those

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[*] *Opusc.* i. 106.

[†] *Phil. Mag.* v. 99.

bodies which we are at present obliged to consider as simple, because they have not yet been decomposed, and of which accordingly we must suppose that vegetables are ultimately composed. These bodies amount to 15, namely,

Substances found in plants.

1. Oxygen,
2. Sulphur,
3. Phosphorus,
4. Carbon,
5. Hydrogen,
6. Azot,
7. Iron,
8. Manganese,
9. Lime,
10. Magnesia,
11. Silica,
12. Alumina,
13. Potass,
14. Soda,
15. Muriatic acid.

But of these substances there are twelve which compose but a very small proportion indeed of vegetables. Almost the whole of vegetable substances are composed of four ingredients, namely,

Carbon, Oxygen,
Hydrogen, Azot.

Of these the last, namely azot, forms but a small proportion even of those vegetable substances of which it is a constituent part, while into many it does not enter at all: so that, upon the whole, by far the greater part of vegetable substances is composed of carbon, hydrogen, and oxygen. I do not mention caloric and light; concerning the nature of which too little is known to enable us to determine with certainty into what substances they enter.

The substances at present known to chemists, which they have not been hitherto able to decompose, amount (omitting caloric and light) to about 40. Sixteen of these exist in plants; the other 24 belong exclusively to the mineral kingdom: for it is a fact, that no substance

(I mean simple substance) has been hitherto found in the animal kingdom which does not exist also in vegetables.

On the contrary, all the simple substances at present known may be found in minerals. This indeed ought not to surprise us, if we recollect, that the spoils of animals and vegetables, after they have undergone decomposition, are ultimately confounded with minerals, and consequently arranged under the mineral kingdom. Besides, as vegetables draw all their food from the mineral kingdom, it would be absurd to suppose that they contain substances which they could not have procured from minerals. It must follow, therefore, of necessity, that minerals contain all the simple substances which exist in this globe of ours; and that plants owe their diversity merely to different modifications of those principles which they imbibe from the soil. But it is impossible to have any precise notions about a subject so intricate, without considering with some attention the structure of vegetables, the food which they imbibe, and the changes which they produce on that food. These inquiries shall form the subject of the next Chapter; in which I propose to take a view of those phenomena of vegetation which are connected with chemistry, or which may be elucidated by the application of the principles of that science.

CHAP. II.

OF VEGETATION.

We have now seen the different substances which are contained in plants; but we have still to examine the manner in which these substances are produced, and to endeavour to trace the different processes which constitute vegetation. But I must warn the reader not to expect complete information in this Chapter. The wonders of the vegetable kingdom are still but very imperfectly explored; many of the organs of plants are too minute for our senses; and scarcely a single process can be completely traced.

Difficulty of the subject.

The multiplicity of operations continually going on in vegetables at the same time, and the variety of different, and even opposite substances, formed out of the same ingredients, and almost in the same place, astonish and confound us. The order, too, and the skill with which every thing is conducted, are no less surprising. No two operations clash; there is no discord, no irregularity, no disturbance; every object is gained, and every thing is ready for its intended purpose. This is too wonderful to escape our observation, and of too much importance not to claim our attention. Many philosophers, accordingly, distinguished equally by their industry and sagacity, have dedicated a great part of their lives to the study of *vegetation*. But hitherto their success has not been equal to their exertions. No person has been able to detect this *Agent*, always so busy, and performing such wonders, or to discover him at his work; nor have philosophers been much more fortunate in ther attempts to ascertain the instruments which he employs in his operations. A great variety, however, of curious and interesting facts have been discovered. These I shall attempt in the following Sections to collect and arrange, to point out their dependence on each other, and perhaps to deduce such consequences as obviously result from this mutual dependence.

SECT. I.

OF GERMINATION.

Plants produced from seeds.

1. NATURAL historians have proved, by a very complete induction of facts, that all plants arise from *seeds*. The pretended exceptions have disappeared, one after another, as our knowledge of vegetables increased: and now there remains scarcely a single objection intitled to the smallest regard. The late attempt of Girtanner * to revive the doctrine of equivocal generation, deserves no attention whatever; because his conclusions are absolutely incompatible with the *experiments* of Mr Senebier upon the very substance on which his theory is founded.

Seeds composed of three parts,

A SEED consists of three parts: namely, the *cotyle-*

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* *Ann. de Chim.* xxxiv. 35.

dons, the *radicle*, and the *plumula*, which are usually inclosed in a cover.

viz. Cotyledon,

If we take a garden bean, we may perceive each of these three parts with great ease; for this seed is of so large a size, that all its organs are exceedingly distinct. When we strip off the external coats of the bean, which are two, and of different degrees of thickness in different parts, we find that it easily divides into two lobes, pretty nearly of the same size and figure. Each of these lobes is called a *cotyledon* (fig. 37. *a*). The cotyledons of the bean, then, are two in number.

Radicle,

Near that part of the lobes which is contiguous to what is called the *eye* of the bean, there is a small round white body (*b*), which comes out between the two lobes. This body is called the *radicle*.

Plumula.

Attached to the radicle there is another small round body (*c*), which lies between the cotyledons, and wholly within them, so that it cannot be seen till they are separated from each other. This body is called the *plumula*.

The appearance and shape of these three parts differ very much in different seeds, but there is no seed which wants them. The figure and size of the seed depend chiefly upon the cotyledons. This is evidently the case with the bean, and it is so with all other seeds. The number of cotyledons is different in different seeds. Some seeds have only one cotyledon, as the seeds of wheat, oats, barley, and the whole tribe of grasses: some have three; others six, as the seeds of the garden cress; but most seeds, like the bean, have two cotyledons.

Germination

2. When a seed is placed in a situation favourable to vegetation, it very soon changes its appearance. The radicle is converted into a root, and sinks into the earth;

the plumula, on the other hand, rises above the earth, and becomes the trunk or stem. When these changes take place, the seed is said to *germinate:* the process itself has been called *germination*. Seeds do not germinate equally and indifferently in all places and seasons. Germination, therefore, is a process which does not depend upon the seed alone; something external must also affect it.

Requires moisture,

3. It is a well known fact, that seeds will not germinate unless *moisture* have access to them; for seeds, if they are kept perfectly dry, never vegetate at all, and yet their power of vegetating is not destroyed. *Water*, then, is essential to germination. Too much water, however, is no less prejudicial to most seeds than none at all. The seeds of water plants, indeed, germinate and vegetate extremely well in water; but most other seeds, if they are kept in water beyond a certain time, are rotted and destroyed altogether.

Heat,

4. It is well known also, that seeds will not germinate, even though supplied with water, provided the temperature be below a certain degree. No seed, for instance, on which the experiment has been tried, can be made to vegetate at or below the freezing point: yet this degree of cold does not injure the vegetating power of seeds; for many seeds will vegetate as well as ever after having been frozen, or after having been kept in frozen water. We may conclude, then, that a certain degree of heat is necessary for the germination of seeds. And every species of plants seems to have a degree peculiar to itself, at which its seeds begin to germinate; for every seed has a peculiar season at which it begins to germinate, and this season varies with the temperature of the air. Mr Adanson found that seeds,

when sown at the same time in France and in Senegal, always appeared sooner above ground in the latter country, where the climate is hotter, than in France*,

And oxygen gas.

5. Seeds, although supplied with moisture, and placed in a proper temperature, will not germinate, provided atmospherical air be completely excluded from them. Mr Ray found that grains of lettuce did not germinate in the vacuum of an air-pump, but they began to grow as soon as air was admitted to them †. Homberg made a number of experiments on the same subject, which were published in the Memoirs of the French Academy for the year 1693. He found, that the greater number of seeds which he tried refused to vegetate in the vacuum of an air-pump. Some, however, did germinate; but Boyle, Muschenbroek, and Boerhaave, who made experiments on the same subject in succession, proved beyond a doubt that no plant vegetates in the vacuum of an air-pump; and that in those cases in which Homberg's seeds germinated, the vacuum was far from perfect, a quantity of air still remaining in the receiver. It follows, therefore, that no seed will germinate unless atmospherical air, or some air having the same properties, have access to it. It is for this reason that seeds will not germinate at a certain depth below the surface of the earth.

Mr Scheele found that beans would not germinate except oxygen gas were present: Mr Achard afterwards proved, that oxygen gas is absolutely necessary for the germination of all seeds, and that no seed will germinate in azotic gas, or hydrogen gas, or carbonic acid gas, unless these gases contain a mixture of oxygen gas.

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* *Encyc. Method. Physiol. Veget.* 124.

† *Phil. Trans.* No. lxi.

These experiments have been confirmed by Mr Gough, Mr Cruickshank, and many other philosophers. It follows, therefore, that it is not the whole atmospheric air, but merely the oxygen gas which it contains, that is necessary for the germination of seeds.

Nay, Mr Humbolt has ascertained that seeds vegetate more rapidly when steeped in oxy-muriatic acid, or when watered with it; and this acid is well known for the facility with which it parts with its oxygen. This acid seems even to augment the vegetative power of seeds. At Vienna several seeds which had been long kept, and which had constantly refused to germinate, grew readily when treated with this acid*.

Impeded by light.

6. Light also has considerable influence on the germination of seeds. Ingenhousz found that seeds always germinate faster in the dark than when exposed to the light†. His experiments were repeated by Mr Sennebier with equal success‡. But the Abbé Bertholin, who distinguished himself so much by his labours to demonstrate the effect of electricity on vegetation, objected to the conclusions of these philosophers, and affirmed, that the difference in the germination of seeds in the shade and in the light was owing, not to the light itself, but to the difference of the moisture in the two situations; the moisture evaporating much faster from the seeds in the light than from those in the shade; and he affirmed, that when precautions were taken to keep the seeds equally moist, those in the sun germinated sooner than those in the shade§. But when Mr Sennebier repeated his former experiments, and employed

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* *Jour. de Phys.* xlvii. 63

† *Experience sur les Vegetaux*, ii.

‡ *Mem. Physico-Chimique*, iii. 341.

§ *Jour. de Phys.* 1789, Decemb.

every possible precaution to ensure the equality of moisture in both situations, he constantly found the seeds in the shade germinate sooner than those in the light[*]. We may conclude, therefore, that light is injurious to germination; and hence one reason for covering seeds with the soil in which they are to grow.

7. Thus we have seen that seeds will not germinate unless *moisture, heat,* and *oxygen gas* be present; and that they do not germinate well if they are exposed to the action of *light.* Now, in what manner do these substances affect the seed? What are the changes which they produce?

Phenomena of germination.

It was observed before, that all seeds have one or more cotyledons. These cotyledons contain a quantity of farinaceous matter, laid up on purpose to supply the embryo plant with food as soon as it begins to require it. This food, however, must undergo some previous preparation, before it can be applied by the plant to the formation or completion of its organs. Now all the phenomena of germination, which we can perceive, consist in the chemical changes which are produced in that food, and the consequent developement of the organs of the plant.

Cotyledons prepare food,

When a seed is placed in favourable circumstances, it gradually imbibes moisture, and very soon after emits a quantity of carbonic acid gas, even though no oxygen gas be present[†]. If no oxygen gas be present, the process stops here, and no germination takes place. But if oxygen gas be present, it is gradually absorbed by the seed; and at the same time the farina of the cotyledons

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[*] *Encyc. Meth. Physiol. Veget.* 126.

[†] Gough, *Manch. Mem.* iv. 315.—Cruikshank, Rollo *on Diabetes*, p. 452.

assumes a sweet taste resembling sugar: it is therefore converted into sugar, or some substance analogous to it*. Mr Saussure Junior has ascertained that the quantity of oxygen gas absorbed during germination is always proportional to the carbonic acid gas emitted; that is to say, the carbonic acid emitted contains in it precisely the same quantity of oxygen as has been absorbed†. Hence it is evident that the farina is changed into sugar by diminishing its carbon, and of course by augmenting the proportion of its hydrogen and oxygen. This is precisely the process of malting, or of converting grain into malt; during which it is well known that there is a considerable heat evolved; so much indeed, that in certain circumstances grain improperly kept has even taken fire. We may conclude from this, that during the germination of seeds in the earth there is also an evolution of a considerable portion of heat. This indeed might have been expected, as it usually happens when oxygen gas is absorbed.

So far seems to be the work of chemistry alone; at least we have no right to conclude that any other agent interferes; since *hay*, when it happens to imbibe moisture, exhibits nearly the same processes. Carbonic acid gas is evolved, oxygen gas is absorbed, heat is produced so abundantly, that the hay often takes fire: at the same time a quantity of sugar is formed. It is owing to a partial change of the same kind that old hay generally tastes much sweeter than new hay. Now we have no reason to suppose that any agents peculiar to the vegetable kingdom reside in hay; as all vegetation, and all power of vegetating, are evidently destroyed.

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[*] Gough, *Manch. Mem.* iv. 315.—Cruikshank, Rollo *on Diabetes*, p. 452.
[†] *Jour. de Phys.* xlix. 92.

And send it into the radicle,

But when the farina in the seeds of vegetables is converted into sugar, a number of vessels make their appearance in the cotyledon. The reader will have a pretty distinct notion of their distribution by inspecting fig. 38. These vessels may indeed be detected in many seeds before germination commences, but they become much more distinct after it has made some progress. Branches from them have been demonstrated by Grew, Malpighi, and Hedwig, passing into the radicle, and distributed through every part of it. These evidently carry the nourishment prepared in the cotyledons to the radicle; for if the cotyledons be cut off, even after the processes above described are completed, germination, as Bonnet and Sennebier ascertained by experiment, immediately stops. The food therefore is conveyed from the cotyledons into the radicle, the radicle increases in size, assumes the form of a *root*, sinks down into the earth, and soon becomes capable of extracting the nourishment necessary for the future growth of the plant. Even at this period, after the radicle has become a perfect root, the plant, as Sennebier ascertained by experiment, ceases to vegetate if the *cotyledons* be cut off. They are still then absolutely necessary for the vegetation of the plant.

Which becomes a root.

Seminal leaves

The cotyledons now assume the appearance of leaves, and appear above the ground, forming what are called the *seminal leaves* of the plant. After this the *plumula* gradually increases in size, rises out of the earth, and expands itself into branches and leaves. The seminal leaves, soon after this, decay and drop off, and the plant carries on all the processes of vegetation without their assistance.

Mr Eller attempted to shew, that there is a vessel in seeds which passes from the cotyledons to the plumula; but later anatomists have not been able to perceive any such vessel. Even Mr Hedwig, one of the most patient, acute, and successful philosophers that ever examined the structure of vegetables, could never discover any such vessel, although he traced the vessels of the cotyledons even through the radicle. As it does not appear, then, that there is any communication between the cotyledons and the plumula, it must follow that the nourishment passes into the plumula from the radicle: and accordingly we see that the plumula does not begin to vegetate till the radicle has made some progress. Since the plant ceases to vegetate, even after the radicle has been converted into a root, if the cotyledons be removed before the plumula is developed, it follows, that the radicle is insufficient of itself to carry on the processes of vegetation, and that the cotyledons still continue to perform a part. Now we have seen already what that part is; they prepare *food* for the nourishment of the plant. The root, then, is of itself insufficient for this purpose. When the cotyledons assume the form of seminal leaves, it is evident that the nourishment which was originally laid up in them for the support of the embryo plant is exhausted, yet they still continue as necessary as ever. They must therefore receive the nourishment which is imbibed by the root; they must produce some changes on it, render it suitable for the purposes of vegetation, and then send it back again to be transmitted to the plumula.

Digest the food sent by the root.

After the plumula has acquired a certain size, which must be at least a *line*, if the cotyledons be cut off, the plant, as Mr Bonnet ascertained by a number of experiments, afterwards repeated with equal success by Mr

Sennebier, does not cease to vegetate, but it continues always a mere pigmy: its size, when compared with that of a plant whose cotyledons are allowed to remain, being only as 2 to 7 *.

When the plumula has expanded completely into leaves, the cotyledons may be removed without injuring the plant, and they very soon decay of themselves. It appears, then, that this new office of the cotyledons is afterwards performed by that part of the plant which is above ground.

Thus we have traced the phenomena of germination as far as they have been detected. The facts are obvious; but the *manner* in which they are produced is a profound secret. We can neither explain how the food enters into the vessels, how it is conveyed to the different parts of the plant, how it is deposited in every organ, nor how it is employed to increase the size of the old parts, or to form new parts. These phenomena are analogous to nothing in mechanics or chemistry, but resemble exactly the organization and nourishment of animals. They belong therefore to that difficult branch of science known by the name of PHYSIOLOGY.

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* *Encyc. Method. Physiol. Veget.* 42.

SECT. II.

OF THE STRUCTURE OF PLANTS.

When the process of germination is accomplished, the plant is complete in all its parts, and capable of vegetating in a proper soil, for a time and with a vigour proportional to its nature.

Plants composed of

Plants, as every body knows, are very various, and of course the structure of each species must have many peculiarities. Trees have principally engaged the attention of anatomists, on account of their size and the distinctness which they expected to find in their parts. I shall therefore take a tree as an instance of the structure of plants; and I shall do it the more readily, as the greater number of vegetables are provided with analogous organs, dedicated to similar uses.

A tree is composed of a *root*, a *trunk*, and *branches*; the structure of each of which is so similar, that a general description of their component parts will be sufficient. Each of them consists of three parts, the *bark*, the *wood*, and the *pith*.

Bark,

The bark is the outermost part of the tree. It covers the whole plant from the extremity of the roots to the extremity of the branches. It is usually of a green colour; if a branch of a tree be cut across, the bark is easily distinguished from the rest of the branch by this colour. If we inspect such a horizontal section with attention, we shall perceive that the bark itself is composed of three distinct bodies, which, with a little care, may be separated from each other. The outermost of these bodies is called the *epidermis*, the middlemost is called the *parenchyma*, and the innermost, or that next the wood, is called the *cortical layers*.

Epidermis,

The *epidermis* is a thin transparent membrane, which covers all the outside of the bark. It is pretty tough. When inspected with a microscope, it appears to be composed of a number of slender fibres crossing each other, and forming a kind of network. It seems even to consist of different thin retiform membranes, adhering closely together. This, at least, is the case with the epidermis of the birch, which Mr Duhamel separated into six layers. The epidermis, when rubbed off, is reproduced. In old trees it cracks and decays, and new epidermes are successively formed. This is the reason that the trunks of many old trees have a rough surface.

Parenchyma,

The *parenchyma* lies immediately below the epidermis; it is of a deep green colour, very tender, and succulent. When viewed with a microscope, it seems to be composed of fibres which cross each other in every direction, like the fibres which compose a hat. Both in it and the epidermis there are numberless interstices, which have been compared to so many small bladders.

Cortical layers,

The *cortical layers* form the innermost part of the bark, or that which is next to the wood. They consist of several thin membranes, lying the one above the other; and their number appears to increase with the age of the plant. Each of these layers is composed of longitudinal fibres, which separate and approach each other alternately, so as to form a kind of network. The meshes of this network correspond in each of the layers; and they become smaller and smaller in every layer as it approaches the wood. These meshes are filled with a green-coloured cellular substance, which has been compared by anatomists to a number of bladders adhering together, and communicating with each other.

Wood,

The WOOD lies immediately under the bark, and forms by far the greatest part of the trunk and large branches of trees. It consists of concentric layers, the number of which increases with the age of the part. Each of these layers, as Mr Duhamel ascertained, may be separated into several thinner layers, and these are composed chiefly of longitudinal fibres. Hence the reason that wood may be much more easily split asunder than cut across.

Alburnum,

Perfect wood,

The *wood*, when we inspect it with attention, is not, through its whole extent, the same; the part of it next the bark is much softer and whiter, and more juicy than the rest, and has for that reason obtained a particular name; it has been called the *alburnum* or *aubier*. The *perfect wood* is browner, and harder, and denser than the alburnum, and the layers increase in density the nearer they are to the centre. Sir John Hill gave to the innermost layer of wood the name of *corona;* or rather he gave this name to a thin zone which, according to him, lies between the wood and the pith.

Pith,

The PITH occupies the centre of the wood. It is a very spongy body, containing a prodigious number of cells, which anatomists have compared to bladders. In young shoots it is very succulent; but it becomes dry as the plant advances, and at last in the large trunks of many trees disappears altogether.

Leaves.

The LEAVES are attached to the branches of plants by short footstalks. From these footstalks a number of fibres issue, which ramify and communicate with each other in every part of the leaf, and form a very curious network. These fibres may be obtained separately, by keeping the leaf long in moisture. Every other part of it putrefies and falls off, or may be easily rubbed off, and only the fibres remain, constituting a skeleton of the leaf. In every leaf there are two layers of these fibres, forming two distinct skeletons, which had constituted the upper and under surface of the leaf.

The whole leaf is covered with the epidermis of the plant; and this epidermis, as Saussure has shewn, contains in it a great number of glands. The other parts of the bark may also be traced on many leaves; at least Saussure has shewn, that the *bark* of leaves is composed of two different layers. The interstices between the fibres of the leaf are filled up by a pulpy-like substance, to which the green colour of the leaf is owing.

Such is a short description of the most conspicuous parts of plants. A more minute account would have been foreign to the subject of the present Work.

SECT. III.

OF THE FOOD OF PLANTS.

Plants, after they have germinated, do not remain stationary, but are continually increasing in size. A tree, for instance, every season adds considerably to its former bulk. The root sends forth new shoots and the old ones become larger and thicker. The same increment takes place in the branches and the trunk. When we examine this increase more minutely, we find that a new layer of wood, or rather of alburnum, has been added to the tree in every part, and this addition has been made just under the bark. We find, too, that a layer of alburnum has assumed the appearance of perfect wood. Besides this addition of vegetable fibre, a great number of leaves have been produced; and the tree puts forth flowers, and forms seeds.

Plants require food.

It is evident from all this, that a great deal of new matter is continually making its appearance in plants. Hence, since it would be absurd to suppose that they *create* new matter, it must follow that they receive it by some channel or other. Plants, then, require food as well as animals. Now, what is this food, and whence do they derive it? These questions can only be answered by an attentive survey of the substances which are contained in vegetables, and an examination of those substances which are necessary for their vegetation. If we could succeed completely, it would throw a great deal of light upon the nature of soils and of manures, and on some of the most important questions in agriculture. But we are far indeed at present from being able to examine the subject to the bottom.

Water necessary.

1. In the first place, it is certain that plants will not vegetate without water; for whenever they are deprived of it, they wither and die. Hence the well-known use of rains and dews, and the artificial watering of ground. Water, then, is at least an essential part of the food of plants. But many plants grow in pure water; and therefore it may be questioned whether water is not the only food of plants. This opinion was adopted very long ago, and numerous experiments have been made in order to demonstrate it. Indeed, it was the general opi-

nion of the 17th century; and some of the most successful improvers of the physiology of plants, in the 18th century, have embraced it. The most zealous advocates for it were, Van Helmont, Boyle, Bonnet, Duhamel, and Tillet.

Supposed the sole food of plants,

Van Helmont planted a willow, which weighed five pounds, in an earthen vessel filled with soil previously dried in an oven, and moistened with rain water. This vessel he sunk into the earth, and he watered his willow, sometimes with rain, and sometimes with distilled water. After five years it weighed 169¼th lbs. and the earth in which it was planted, when again dried, was found to have lost only two ounces of its original weight. Here, it has been said, was an increase of 164 lb. and yet the only food of the willow was pure water; therefore it follows that pure water is sufficient to afford nourishment to plants. The insufficiency of this experiment to decide the question was first pointed out by Bergman in 1773 *. He shewed, from the experiments of Margraff, that the rain water employed by Van Helmont contained in it as much earth as could exist in the willow at the end of five years. For, according to the experiments of Margraff, 1 lb. of rain water contains 1 gr. of earth †. The growth of the willow, therefore, by no means proves that the earth which plants contain has been formed out of water. Besides, as Mr Kirwan has remarked ‡, the earthen vessel must have often absorbed moisture, from the surrounding earth, impregnated with whatever substance that earth contained; for unglazed earthen vessels, as

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* *Opusc.* v. 92.

† Ibid. ii. 15. and 19.

‡ *Irish Trans.* v. 150.

But without reason.

Hales [*] and Tillet [†] have shewn, readily transmit moisture. Hence it is evident that no conclusion whatever can be drawn from this experiment; for all the substances which the willow contained, except water, may have been derived from the rain water, the earth in the pot, and the moisture imbibed from the surrounding soil.

The experiments of Duhamel and Tillet are equally inconclusive; so that it is impossible from them to decide the question, Whether water be the sole nourishment of plants or not? We owe the solution of this difficulty to the experiments of Mr Hassenfratz.

He analysed the bulbous roots of hyacinths, in order to discover the quantity of water, carbon, and hydrogen, which they contained; and by repeating the analysis on a number of bulbs, he discovered how much of these ingredients was contained in a given weight of the bulb. He analysed also kidney beans and cress seeds in the same manner. Then he made a number of each of these vegetate in pure water, taking the precaution to weigh them beforehand, in order to ascertain the precise quantity of carbon which they contained. The plants being then placed, some within doors, and others in the open air, grew and flowered, but produced no seed. He afterwards dried them, collecting with care all their leaves and every other part which had dropt off during the course of the vegetation. On submitting each plant to a chemical analysis, he found that the quantity of carbon, which it contained, was somewhat less than the quantity which existed in the bulb or the seed from which the plant had sprung [‡].

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[*] *Veget. Stat.* i. 5.

[†] *Mem. Par.* 1772, 298.

[‡] *Ann. de Chim.* xiii. 183.

Hence it follows irresistibly, that plants growing in pure water do not receive any increase of *carbon*; that the water merely serves as a vehicle for the carbonaceous matter already present, and diffuses it through the plant. Water, then, is not the sole food of plants; for all plants during vegetation receive an increase of carbonaceous matter, without which they cannot produce perfect seeds, nor even continue to vegetate beyond a certain time; and that time seems to be limited by the quantity of carbonaceous matter contained in the bulb or the seed from which they grow. For Duhamel found, that an oak which he had raised by water from an acorn, made less and less progress every year. We see, too, that those bulbous roots, such as hyacinths, tulips, &c. which are made to grow in water, unless they be planted in the earth every other year, refuse at last to flower, and even to vegetate; especially if they produce new bulbous roots annually, and the old ones decay.

A certain proportion only requisite.

So far, indeed, is water from being the sole food of plants, that in general only a certain proportion of it is serviceable, too much being equally prejudicial to them as too little. Some plants, it is true, grow constantly in water, and will not vegetate in any other situation; but the rest are entirely destroyed when kept immersed in that fluid beyond a certain time. Most plants require a certain degree of moisture in order to vegetate well. This is one reason why different soils are required for different plants. Rice, for instance, requires a very wet soil: were we to sow it in the ground on which wheat grows luxuriously, it would not succeed; and wheat, on the contrary, would rot in the rice ground.

We should, therefore, in choosing a soil proper for the plants which we mean to raise, consider the quantity of moisture which is best adapted for them, and choose our soil accordingly. Now, the dryness or moisture of a soil depends upon two things; the nature and proportions of the earths which compose it, and the quantity of rain which falls upon it. Every soil contains at least three earths, silica, lime, and alumina, and sometimes also magnesia. The silica is always in the state of sand. Now soils retain moisture longer or shorter according to the proportions of these earths. Those which contain the greatest quantity of sand retain it the shortest, and those which contain the greatest quantity of alumina retain it longest. The first is a dry, the second a wet soil. Lime and magnesia are intermediate between these two extremes: they render a sandy soil more retentive of moisture, and diminish the wetness of a clayey soil. It is evident, therefore, that, by mixing together proper proportions of these four earths, we may form a soil of any degree of dryness and moisture that we please.

But whatever be the nature of the soil, its moisture must depend in general upon the quantity of rain which falls. If no rain at all fell, a soil, however retentive of moisture it be, must remain dry; and if rain were very frequently falling, the soil must be open indeed, if it be not constantly wet. The proportion of the different earths in a soil, therefore, must depend upon the quantity of rain which falls. In a rainy country, the soil ought to be open; in a dry country, it ought to be retentive of moisture. In the first, there ought to be a greater proportion of sand; in the second, of clay.

Earth necessary,

2. Almost all plants grow in the earth, and every soil contains at least silica, lime, alumina, and often

magnesia. The use of these earths is to administer the proper quantity of water to the vegetables which grow in the soil. But as all plants contain earths as a part of their ingredients, is it not probable that earths also serve as a food for plants? It has not yet indeed been shewn, that those plants which vegetate in pure water do not contain the usual quantity of earth: but as earths are absolutely necessary for the perfect vegetation of plants, as they are contained in all plants, and are even found in their juices, we can scarcely doubt that they are actually imbibed, though only in small quantities. Mr Tennant has ascertained, that magnesia, when uncombined with carbonic acid gas, is injurious to corn when employed as a manure; and that lime, which contains a mixture of magnesia, likewise injures corn[*]. This important fact demonstrates, that earths are not mere vehicles for conveying water to plants. The same conclusion follows irresistibly from the experiments of Saussure Junior. That philosopher analysed the following plants growing in a granitic and in a calcareous soil[†]; namely, *pinus abies*, *pinus larix*, *rhododendron ferrugineum*, *vaccinium myrtillus*, *juniperus communis*. The result was, that the plants which grew in the granitic soil contained most water. The proportion of charcoal was nearly the same in both; but the propor-

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[*] *Phil. Trans.* 1799, p 2.

[†] These soils were composed of the following ingredients:

Granitic.	*Calcareous.*
73.25 silica	98.000 carbonat of lime
13.25 alumina	0.625 alumina
1.74 lime	0.625 oxide of iron
9.00 iron and manganese	0.025 petroleum
97.24	99.275

Book IV.

tion of earths corresponded nearly with the nature of the soil. The plants which grew in the granitic soil contained a considerable proportion of silica and metallic oxides; those which grew in the calcareous, little or none of these bodies, but a greater proportion of calcareous earth than the granitic plants. Thus the pinus abies, the product of each of these soils, yielded the following proportions of fixed bodies:

	Granitic.	Calcar.
Potass	3.60	15
Alkaline sulphats and muriats	4.24	
Carbonat of lime	46.34	63
Carbonat of magnesia	6.77	0
Silica	13.49	0
Alumina	14.86	16
Metallic oxides	10.52	0
	99.82	94 *

And salts,

3. All plants contain likewise various saline substances; and if we analyse the most fertile soils, and the richest manures, we never find them destitute of these substances. Hence it is probable that different salts enter as ingredients into the food of plants. It is probable also, that every plant absorbs particular kinds of salts. Thus sea plants yield soda by analysis, while inland plants furnish potass. The potass contained in plants has indeed been supposed to be the produce of vegetation; but this has not been proved in a satisfactory manner. We find potass in the very juices of plants, even more abundantly than in the vegetable fibres themselves. But this subject is still buried in obscurity; and indeed it is extremely difficult to make

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* *Phil. Mag.* viii. 185.—*Jour. de Phys.* lii. 27.

decisive experiments, on account of the very small quantity of potass which most plants contain.

The phosphorus, too, and the iron, and other metals which are found in plants, are no doubt absorbed by them as a part of their food. We may suppose also, that the sulphuric and muriatic acids, and perhaps even the nitric acid, when found in plants, are imbibed by them along with the rest of their aliment.

Nothing is at present known concerning those saline substances which form an essential part of the food of plants; though it has been long remarked that certain salts are useful as manures.

And carbon,

4. Water, then, and earths, and perhaps also salts, form a part of the food of plants. But plants contain carbon, which cannot be derived from any of these substances; consequently some substance or other besides, which contains carbon, must constitute a part of the food of plants.

Mr Giobert mixed together the four earths, silica, alumina, lime, magnesia, in the proper proportions, to constitute a fertile soil; and after moistening them with water, planted several vegetables in them; but none of his plants grew well, till he moistened his artificial soil with water from a dunghill*. Now it is certain, from the experiments of Hassenfratz, that this water contains carbon; for when evaporated, it constantly leaves behind it a residuum of charcoal†. We know likewise, from a great variety of experiments, that all fertile soils contain a considerable quantity of carbonaceous matter; for all of them, when exposed to heat, are susceptible of partial combustion, during which a quantity of car-

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* *Encyc. Meth. Phys. Veget.* p. 275.

† *Ann. de Chim.* xiv. 56.

bonic acid gas escapes. Thus Fourcroy and Hassenfratz found that 9216 parts of fertile soil contained 305 parts of carbon, besides 279 parts of oil; which, from the analysis of Lavoisier, we may suppose to contain about 220 parts of carbon. It follows, therefore, from the experiments of these chemists*, that 9216 parts of soil contain 525 parts of carbon. But these 9216 parts of soil contained 806 parts of roots of vegetables which were excluded from the analysis; consequently a fertile soil contains (exclusive of the roots of vegetables) about one-sixteenth of its weight of carbon.

Which must be in a particular state.

But the carbon must exist in the soil in a particular state of combination, otherwise it does not answer as food for plants: For instance, powdered pitcoal, mixed with earths, is not found to act, at least immediately, as a manure; yet pitcoal contains a very great quantity of carbon. Farther, it appears from the experiments of Mr Hassenfratz, that substances employed as manures produce effects in times proportioned to their degree of putrefaction; those substances which are most putrid producing the most speedy effects, and of course soonest losing their efficacy. Having manured two pieces of the same kind of soil, the one with a mixture of dung and straw highly putrefied, the other with the same mixture newly made, and the straw almost fresh, he observed that, during the first year, the plants which grew on the land manured with the putrefied dung produced a much better crop than the other: but the second year (no new dung being added), the ground which had been manured with the unputrefied dung

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[*] *Encyc. Meth. Physiol. Veget.* p. 277.

produced the best crop; the same thing took place the third year; after which, both seemed to be equally exhausted *. Here it is evident that the putrefied dung acted soonest, and was soonest exhausted. It follows from this, that carbon only acts as a manure when in a particular state of combination; and this state, whatever it may be, is evidently produced by putrefaction. Another experiment of the same chemist renders this truth still more evident. He allowed shavings of wood to remain for about ten months in a moist place till they began to putrefy, and then spread them over a piece of ground by way of manure. The first two years this piece of ground produced nothing more than others which had not been manured at all; the third year it was better, the fourth year it was still better, the fifth year it reached its maximum of fertility; after which it declined constantly till the ninth, when it was quite exhausted †. Here the effect of the manure evidently depended upon its progress in putrefaction.

The particular state into which carbon must be reduced before it be fit for the food of plants is not known exactly, the different combinations of carbon having been in a great measure overlooked. And yet it is evident, that it is only by an accurate examination of these combinations, and a thorough analysis of manures, in order to discover what particular combinations of carbon exist in them, and in what the most efficacious manures differ from the rest, that we can expect to throw complete light upon the nature and use of manures, one of the most important subjects to which the farmer can direct his attention. We know, from the

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* *Ann. de Chim.* xiv. 57.

† Ibid. p. 58.

experiments of Mr Hassenfratz, that all those manures which act with efficacy and celerity contain carbon in such a state of combination, that it is soluble in water; and that the efficacy of the manure is proportional to the quantity of carbon so soluble *. He found that all efficacious manures gave a brown colour to water; and that the water so coloured, when evaporated, left a residuum, which consisted in a great measure of carbon †. He observed, too, that the soil which gives the deepest colour to water, or which contains the greatest quantity of carbon soluble in water, is, other things being the same, the most fertile.

This is not, however, to be understood without limitation; for it is well known that if we employ excessive quantities of manure, we injure vegetation instead of promoting it. This is the reason that plants will not, as Mr Duhamel found by experiment, vegetate in saturated solutions of dung †.

Not carbonic acid.

One of the combinations of carbon which is soluble in water, and with which we are best acquainted, is carbonic acid gas. It has been supposed by many philosophers, particularly by Mr Sennebier, that this gas, dissolved in water, supplies plants with a great part of their carbon. But Mr Hassenfratz, on making the experiment, found that the plants which he raised in water, impregnated with carbonic acid gas, differed in no respect from those which grew in pure water, and did not contain a particle of carbon which had not existed

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[*] It is not improbable that the charcoal of manure is rendered soluble in water by being combined with potass. Every chemist must have perceived that the combination is easily formed, and that it is extremely difficult to free potass altogether from charcoal.

[†] *Ann. de Chim.* xiv. 56. [†] *Mem. Par.* 1748.

But that gas is useful.

in the seeds from which they sprung [*]. This experiment proves that carbonic acid gas, dissolved in water, does not serve as food for plants. It appears, however, from the experiments of Ruckert, that when plants growing in soil are watered daily with water impregnated with carbonic acid gas, they vegetate faster than when this watering is omitted. He planted two beans in pots of equal dimensions, filled with garden mould. One of these was watered almost daily with distilled water, the other with water, every ounce of which was impregnated with half a cubic inch of carbonic acid gas. Both were placed in the open air, but in a situation where they were secure from rain. The bean treated with the water impregnated with carbonic acid gas appeared above ground nine days before the other, and produced 25 beans; whereas the other produced only 15. The same experiment was tried on other plants with equal success [†]. This shews us that carbonic acid gas is somehow or other useful to plants when they vegetate in mould; but it gives us no information about its mode of acting. Some soils, we know, are capable of decomposing it; for some soils contain the green oxide of iron: and Gadolin has proved, that such soils have the property of decomposing carbonic acid gas [‡]. Indeed almost all soils contain iron, either in the state of the brown or the green oxide; and Beaumé has shewn that oils convert the brown oxide of iron into the green [§]. Now dung contains a quantity of oily substance; and this is the case also with rich soils. One use of manures, therefore, may be, to reduce the brown

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[*] *Ann. de Chim.* xiii. 320.

[†] Crell's *Annals*, 1788, ii. 399.

[‡] Ibid. 1791, i. 53.

[§] Kirwan, *Irish Trans.* v. 167.

oxide of iron to the green, that it may be capable of decomposing carbonic acid gas; and the carbon, thus precipitated, may enter into some new combination, in which state it may serve as food for plants. But it is more probable, that the carbonic acid enters the plant combined with some other body, and that its decomposition takes place within the plant itself.

Soils absorb oxygen.

Ingenhousz observed long ago, that soils have the property of absorbing oxygen from the atmosphere *. This observation has been lately confirmed by Humbolt; and upon repeating the experiment, I found that new turned-up soil does absorb oxygen from the air, giving out at the same time a portion of carbonic acid gas. It can scarcely be doubted that this absorption has an influence on vegetation, especially as watering plants with weak solutions of oxy-muriatic acid accelerates vegetation †. But we know too little of the subject at present to be able to specify precisely what that influence is.

Food absorbed by the ends of the roots.

Such is the present state of our knowledge respecting the food of plants, as far as it is supplied by the soil in which they vegetate. It is probable that it is imbibed by the extremities of the roots only; for Duhamel observed, that the portion of the soil which is soonest exhausted is precisely that part in which the greatest number of the extremities of roots lies ‡. This shews us the reason why the roots of plants are continually increasing in length. By this means they are enabled, in some measure, to go in quest of nourishment. The extremities of the roots seem to have

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* *Jour. de Phys.* xlv. 460.

† Ingenhousz.

‡ *Physique des Arbres*, ii. 239.

peculiar structure adapted for the imbibing of moisture. If we cut off the extremity of a root, it never increases any more in length: therefore its use as a root has been in a great measure destroyed. But its sides send out fibres which act the part of roots, and imbibe food by their extremity. Nay, in some cases, when the extremity of a root is cut off, the whole decays, and a new one is formed in its place. This, as Dr Bell informs us, is the case with the hyacinth *.

It must be in a state of solution.

The extremities of the roots contain no visible opening. Hence we may conclude, that the food which they imbibe, whatever it may be, must be in a state of solution; while the absolute necessity of water renders it probable that water is the solvent. And, in fact, the carbon, in all active manures, is in such a state of combination that it is soluble in water. All the salts which we can suppose to make a part of the food of plants are more or less soluble in water. This is the case also with lime, whether it be pure or in the state of a salt; magnesia and alumina may be rendered so by means of carbonic acid gas; and Bergman, Macie, and Klaproth, have shewn that even silica may be dissolved in water. We can see, therefore, in general, though we have no precise notions of the very combinations which are immediately imbibed by plants, that all the substances which form essential parts of that food *may* be dissolved in water.

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* *Manch. Mem.* ii. 412.

SECT. IV.

OF THE SAP OF PLANTS.

SINCE the food of plants is imbibed by their roots in a fluid state, it must exist in plants in a fluid state; and unless it undergoes alterations in its composition just when imbibed, we may expect to find it in the plant unaltered. If there were any method of obtaining this fluid food from plants before it has been altered by them, we might analyse it, and obtain by that means a much more accurate knowledge of the food of plants than we can by any other method. This plan indeed must fail, provided the food undergoes alteration just when it is absorbed by the roots: but if we consider, that when one species of tree is grafted upon another, each bears its own peculiar fruit, and produces its own peculiar substances, we can scarcely avoid thinking that the *great* changes, at least which the food undergoes after absorption, are produced, not in the roots, but in other parts of the plant.

Sap of plants

If this conclusion be just, the food of plants, after being imbibed by the roots, must go directly to those organs where it is to receive new modifications, and to be rendered fit for being assimilated to the different parts of the plant. There ought therefore to be certain juices continually ascending from the roots of plants; and these juices, if we could get them pure and unmixed with the other juices or fluids which the plant must contain, and which have been secreted and formed from these primary juices, would be, very nearly at least, the food as it was imbibed by the plant. Now during the vegetation of plants, there actually is a *juice* continually ascending from their roots. This juice has been called the *sap*, the *succus communis*, or the *lymph* of plants.

Flows out in the spring.

1. The first step towards an accurate knowledge of the food, and of the changes which take place during vegetation, is an analysis of the sap. The sap is most abundant during the spring. At that season, if a cut be made through the bark and part of the wood of some trees, the sap flows out very profusely. The trees are then said to *bleed*. By this contrivance any quantity of sap we think proper may be collected. It is not probable, indeed, that by this method we obtain the ascending sap in all its purity: it is no doubt mixed with the peculiar juices of the plant; but the less progress vegetation has made, the purer we may expect to find it; both because the peculiar juices must be in much smaller quantity, and because its quantity may be supposed to be greater. We should therefore examine the sap as early in the season as possible, and at all events before the leaves have expanded.

Analysed.

For the most complete set of experiments hitherto made upon the sap, we are indebted to Mr Vauquelin *. He has neglected to inform us of the state of the tree when the sap which he analysed was taken from it; so that we are left in a state of uncertainty with respect to the purity of the sap: but from the comparison which he has put it in our power to draw between the state of the sap at different successive periods, we may in some measure obviate this uncertainty.

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* *Ann. de Chim.* xxxi. 32. and *Jour. de Phys.* xlix. 38.

Book IV.

He found that 1039 parts of the sap of the ulmus campestris, or common elm, were composed of

1027.904	water and volatile matter
9.240	acetite of potass
1.060	vegetable matter
0.796	carbonat of lime

Besides some slight traces of sulphuric and muriatic acids.

On analysing the same sap somewhat later in the season, Mr Vauquelin found the quantity of vegetable matter a little increased, and that of the carbonat of lime and acetite of potass diminished. Still later in the season the vegetable matter was farther increased, and the other two ingredients farther diminished. The carbonat of lime was held in solution by carbonic acid, of which there existed a considerable excess in the sap. It is to this acid gas that the air-bubbles, which so often accompany the sap as it issues from the tree, are owing *.

If these experiments warrant any consequence to be drawn from them, they would induce us to suppose that the carbonat of lime and acetite of potass were contained in the pure ascending sap, and that part at least of the vegetable matter was derived from the peculiar juices altered by the secreting organs of the plant; for the two salts diminished in quantity, and the vegetable matter increased as the vegetation of the tree advanced. Now this is precisely what ought to have taken place, on the supposition that the sap became more and more mixed with the peculiar juices of the tree, as we are supposing it to do. If these conclusions have any so-

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* See Coulomb, *Jour. de Phys.* xlix. 392.

lidity, it follows from them, that carbonat of lime and acetite of potass are absorbed by plants as a part of their food. Now these salts, before they are absorbed, must be dissolved in water. But the carbonat of lime may be dissolved in water by the help of carbonic acid. This shews us how water saturated with carbonic acid may be useful to plants vegetating in a proper soil, while it is useless to those that vegetate in pure water. In the pure water there is no carbonat of lime to be dissolved; and therefore carbonic acid gas cannot enter into a combination which renders it proper for becoming the food of plants. Part of the vegetable matter was precipitated from the sap by alcohol. This part seems to have been gummy. Now gums, as is well known, are produced by vegetation.

The sap of the fagus sylvatica, or beech, contained the following ingredients:

Water,
Acetite of lime with excess of acid,
Acetite of potass,
Gallic acid,
Tan,
A mucous and extractive matter,
Acetite of alumina.

Although Mr Vauquelin made two different analyses of this sap at different seasons, it is impossible to draw any satisfactory conclusions from them, as he has not given us the proportions of the ingredients. It seems clear that the gallic acid and tan were combined together; for the sap tasted like the infusion of oak bark. The quantity of each of these ingredients increased as vegetation advanced; for the colour of the second sap collected later was much deeper than that of the first. This shews us that these ingredients were produced by vegetation, and that they did not form a part of the ascending sap. Probably they were derived from the bark of the tree. The presence of alumina, and the absence of carbonic acid gas, would seem to indicate that all plants do not imbibe the very same food.

The sap of the carpinus sylvestris contains water, acetite of potass, acetite of lime, sugar, mucilage, vegetable extract. It cannot be doubted that the sugar and the mucilage are the produce of vegetation.

The sap of the betula alba, or common birch, contains water, sugar, vegetable extract, acetite of lime, acetite of alumina, and acetite of potass.

These experiments are curious, and certainly add to the precision of our notions concerning the food of plants; but they are not numerous enough to intitle us to draw conclusions. They would seem to shew, either that acetite of potass and lime are a part of the food of plants, or at least some substances which have the property of assuming these combinations.

Whether the food be altered by the roots.

2. These experiments lead to the conclusion that acetous acid forms a component part of the sap. Now it is not easy to suppose that this substance is actually absorbed by the roots in the state of acetous acid. The thing might be determined by examining the mould in which plants grow. This examination indeed has been performed, and the acetites have been found, but not in any great quantity. Is it not probable that the food, after it is imbibed, is somewhat modified and altered by the roots? In what manner this is done we cannot say, as we know very little about the vascular structure of the roots. We may conclude, how-

ever, that this modification is nearly the same in most plants: for one plant may be engrafted on another, and each continue to produce its own peculiar products; which could not be, unless the proper substances were conveyed to the digestive organs of all. There are several circumstances, however, which render the modifying power of the roots somewhat probable. The strongest of these is the nature of the ingredients found in the sap. It is even possible that the roots may, by some means or other, throw out again some part of the food which they have imbibed as excrementitious. This has been suspected by several physiologists, and there are several circumstances which render it probable. It is well known that some plants will not vegetate well after others; and that some again vegetate unusually well when planted in ground where certain plants had been growing. These facts, without doubt, may be accounted for on other principles. If there be any excrementitious matter emitted by the roots, it is much more probable that this happens in the last stage of vegetation. That is to say, when the food, after digestion, is applied to the purposes which the root requires. But the fact ought to be supported by experiments, otherwise it cannot be admitted.

3. The sap, as Dr Hales has shewn us, ascends with a very considerable force. It issued during the bleeding season with such impetuosity from the cut end of a vine branch, that it supported a column of mercury 32½ inches high*.

Now what is the particular channel through which the sap ascends, and what is the cause of the force with

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* *Veg. Stat.* i. 105.

which it moves? These are questions which have excited a great deal of the attention of those philosophers who have made the physiology of vegetables their particular study; but the examination of them is attended with so many difficulties that they are very far from being decided.

Sap ascends

It is certain that the sap flows from the roots towards the summit of the tree. For if in the bleeding season a number of openings be made in the tree, the sap begins first to flow from the lowest opening, then from the lowest but one, and so on successively, till at last it makes its appearance at the highest of all. And when Duhamel and Bonnet made plants vegetate in coloured liquors, the colouring matter, which was deposited in the wood, appeared first in the lowest part of the tree, and gradually ascended higher and higher, till at last it reached the top of the tree, and tinged the very leaves.

Through the wood

It seems certain, too, that the sap ascends through the wood, and not through the bark of the tree: for a plant continues to grow even when stript of a great part of its bark; which could not happen if the sap ascended through the bark. When an incision, deep enough to penetrate the bark, and even part of the wood, is carried quite round a branch, provided the wound be covered up from the external air, the branch continues to vegetate as if nothing had happened; which could not be the case if the sap ascended between the bark and the wood. It is well known, too, that in the bleeding season little or no sap can be got from a tree unless our incision penetrate deeper than the bark.

These conclusions have been confirmed by the experiments made lately by Coulomb and Knight. Coulomb observed that no sap ever flows from the poplar till the tree be cut nearly to the centre *. Mr Knight observed that coloured infusions always pass through the alburnum, and that whenever the alburnum is cut through the plant dies †.

In peculiar vessels.

As the sap is never found in the parenchyma, it must of necessity be confined in particular vessels; for if it were not, it would undoubtedly make its appearance there. Now what are the vessels through which the sap ascends?

Grew and Malpighi, the first philosophers who examined the structure of plants, took it for granted that the woody fibres were tubes, and that the sap ascended through them. For this reason they gave these fibres the name of *lymphatic vessels*. But they were unable, even when assisted by the best microscopes, to detect any thing in these fibres which had the appearance of a tube; and succeeding observers have been equally unsuccessful. The conjecture therefore of Malpighi and Grew, about the nature and use of these fibres, remains totally unsupported by any proof. Duhamel has even gone far to overturn it altogether. For he found that these woody fibres are divisible into smaller fibres, and these again into still smaller; and even, by the assistance of the best microscopes, he could find no end of this subdivision ‡. Now granting these fibres to be vessels, it is scarcely possible, after this, to suppose that the sap really moves through tubes, whose diameters are almost infinitely small. There are, however, vessels in plants which may easily be distinguished by

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* *Jour. de Phys.* xlix. 392.

† *Phil. Trans.* 1801, p. 336.

‡ *Physique des Arbres*, i. 57.

the help of a small microscope, and even in many cases by the naked eye. These were seen, and distinctly described, by Grew and Malpighi. They consist of a fibre twisted round like a corkscrew. If we take a small cylinder of wood, and wrap round it a slender brass wire, so closely that all the rings of the wire touch each other, and if, after this, we pull out the wooden cylinder altogether, the brass wire thus twisted will give us a very good representation of these vessels. If we take hold of the two ends of the brass wire thus twisted, and pull them, we can easily draw out the wire to a considerable length. In the same manner, when we lay hold of the two extremities of these vessels, we can draw them out to a great length. Malpighi and Grew finding them always empty, concluded that they were intended for the circulation of the air through the plant, and therefore gave them the name of *tracheæ;* which word is used to denote the *windpipe* of animals. These *tracheæ* are not found in the bark; but Hedwig has shewn that they are much more numerous in the wood than was supposed; and that they are of very different diameters; and Reichel has demonstrated that they go to the minutest branches, and spread through every leaf. He has shewn, too, that they contain sap; and Hedwig has proved that the notion which generally prevailed of their containing nothing but air, arose from this circumstance, that the larger *tracheæ,* which alone were attended to, lose their sap as soon as they are cut; and of course, unless they are inspected the instant they are divided, they appear empty[*]. Is it not probable, then, or rather is it not certain, from the

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[*] *Fundament. Hist. Nat. Muscor. Frondes,* Part i. p. 54.

discoveries of that very ingenious physiologist, that the tracheæ are, in reality, the sap vessels of plants? Indeed it seems established by the experiments both of Reichel and Hedwig, that all, or almost all, the vessels of plants may, if we attend only to their structure, be denominated *tracheæ*.

Its ascension

4. But by what powers is the sap made to ascend in these vessels? And not only to ascend, but to move with very considerable force; a force, as Hales has shewn, sufficient to overcome the pressure of 43 feet perpendicular of water*?

Ascribed to its levity;

Grew ascribed this phenomena to the levity of the sap; which, according to him, entered the plant in the state of a very light vapour. But this opinion will not bear the slightest examination. Malpighi supposed that the sap was made to ascend by the contraction and dilation of the air contained in the air vessels. But even were we to grant that the tracheæ are air vessels, the sap, according to this hypothesis, could only ascend when a change of temperature takes place; which is contrary to fact. And even if we were to wave every objection of that kind, the hypothesis would not account for the circulation of the sap, unless the sap vessels be provided with valves. Now the experiments of Hales and Duhamel shew that no valves can possibly exist in them. For branches imbibe moisture nearly equally by either end; and consequently the sap moves with equal facility both upwards and downwards, which it could not do were there valves in the vessels. Besides, it is known, from many experiments, that we may convert the roots of a tree into the branches, and

To the contraction of air;

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[*] *Veget. Stat.* i. 107.

the branches into the roots, by covering the branches with earth, and exposing the roots to the air. Now this would be impossible if the sap vessels were provided with valves. The same remarks overturn the hypothesis of Mr de la Hire, which is merely that of Malpighi, expressed with greater precision, and with a greater parade of mechanical knowledge. Like Borelli, he placed the ascending power of the sap in the parenchyma. But his very experiments, had he attended to them with care, would have been sufficient to shew the imperfection of his theory.

The greater number of philosophers (for it is needless to mention those who, like Perrault, had recourse to fermentation, nor those who introduced the weight of the atmosphere) have ascribed the motion of the sap to *capillary attraction.*

To capillary attraction,

There exists an attraction between many solid bodies and liquids; in consequence of which, if these solid bodies be formed into small tubes, the liquid enters them, and rises in them to a certain height. But this is perceptible only when the diameter of the tube is very small. Hence the attraction has been denominated *capillary.* We know that there is such an attraction between vegetable fibres and watery liquids; for such liquids will ascend through dead vegetable matter. It is highly probable, therefore, that the food of plants enters the roots, in consequence of the capillary attraction which subsists between the sap vessels and the liquid imbibed. This species of attraction, then, will account perfectly well for the entrance of moisture into the mouths of the sap vessels: But will it account also, as some have supposed, for the ascent of the sap, and for the great force with which it ascends?

The nature and laws of capillary attraction have been very much overlooked by philosophers. But we know enough concerning it to enable us to decide the present question. It consists in a certain attraction between the particles of the liquid and of the tube. It has been demonstrated, that it does not extend, or at least that it produces no sensible effect, at greater distances than $\frac{1}{1000}$ part of an inch. It has been demonstrated, that the water ascends, not by the capillary attraction of the whole tube, but of a slender film of it; and Clairaut has shewn that this film is situated at the lowermost extremity of the tube *. This film attracts the liquid with a certain force; and if this force be greater than the cohesion between the particles of the liquid, part enters the tube, and continues to enter, till the quantity above the attracting film of the tube just equals, by its weight, the excess of the capillary attraction between the tube and the liquid, above the cohesion of the liquid. The quantity of water, therefore, in the tube is pretty nearly the measure of this excess; for the attracting film is probably very minute.

But without reason.

It has been demonstrated, that the heights to which liquids rise in capillary tubes, are inversely as the diameter of the tube. Consequently the smaller the diameter of the tube, the greater is the height to which the liquid will rise. But the particles of water are not infinitely small; therefore whenever the diameter of the

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* The action of all the other films, of which the tube is composed, on the water, as far as it is measured by its effect, is nothing at all. For every particle of water in the tube (except those attracted by the undermost film) is attracted upwards and downwards by the same number of films: it is therefore precisely in the same state as if it were not attracted at all.

tube is diminished beyond a certain size, water cannot ascend in it, because its particles are now larger than the bore of the tube. Consequently the rise of water in capillary tubes must have a limit : if they exceed a certain length, how small soever their bore may be, water will either not rise to the top of them, or it will not enter them at all. We have no method of ascertaining the precise height to which water would rise in a capillary tube, whose bore is just large enough to admit a single particle of water. Therefore we do not know the limit of the height to which water may be raised by capillary attraction. But whenever the bore is diminished beyond a certain size, the quantity of water which rises in it is too small to be sensible. We can easily ascertain the height which water cannot exceed in capillary tubes before this happens ; and if any person calculate, he will find that this height is not nearly equal to the length of the sap vessels of many plants. But besides all this, we see in many plants very long sap vessels, of a diameter too large for a liquid to rise in them a single foot by capillary attraction, and yet the sap rises in them to very great heights.

If any person says that the sap vessels of plants gradually diminish in diameter as they ascend ; and that, in consequence of this contrivance, they act precisely as an indefinite number of capillary tubes, one standing upon another, the inferior serving as a reservoir for the superior—I answer, that the sap may ascend by that means to a considerable height ; but certainly not in any greater quantity than if the whole sap vessel had been precisely of the bore of its upper extremity ; for the quantity of sap raised must depend upon the bore of the upper extremity, because it must all pass through that extremity.

But farther, if the sap moved only in the vessels of plants by capillary attraction, it would be so far from flowing out at the extremity of a branch, with a force sufficient to overcome the pressure of a column of water 43 feet high, that it could not flow out at all. It would be impossible in that case for any such thing as the bleeding of trees ever to happen.

If we take a capillary tube, of such a bore that a liquid will rise in it six inches, and after the liquid has risen to its greatest height, break it short three inches from the bottom, none of the liquid in the under half flows over. The tube, thus shortened, continues indeed full, but not a single particle of liquid ever escapes from it. And how is it possible for it to escape? The film, at the *upper* extremity of the tube, must certainly have as strong an attraction for the liquid as the film at the *lower* extremity. As part of the liquid is within its attracting distance, and as there is no part of the tube above to counterbalance this attraction, it must of necessity attract the liquid nearest it, and with a force sufficient to counterbalance the attraction of the undermost film, how great soever we may suppose it. Of course no liquid can be forced up, and consequently none can flow out of the tube. Since then the sap *flows out* at the upper extremity of the sap vessels of plants, we are absolutely certain that it does not ascend in them merely by its capillary attraction, but that there is some other cause.

It is impossible therefore to account for the motion of the sap in plants by any mechanical or chemical principles whatever; and he who ascribes it to these principles has not formed to himself any clear or accurate conception of the subject. We know indeed that heat is an agent; for Dr Walker found that the ascent of the sap is much promoted by heat, and that after it had begun to flow from several incisions, cold made it give over flowing from the higher orifices while it continued to flow at the lower *. But this cannot be owing to the dilating power of heat; for unless, the sap vessels of plants were furnished with valves (and they have no valves), dilatation would rather retard than promote the ascent of the sap. Consequently the effect of heat can give us no assistance in explaining the ascent of the sap upon mechanical and chemical principles.

The vessels must contract.

We must therefore ascribe it to some other cause: the vessels themselves must certainly act. Many philosophers have seen the necessity of this, and have accordingly ascribed the ascent of the sap to *irritability*. But the first person who gave a precise view of the manner in which the vessels probably act was Saussure. He supposes that the sap enters the open mouths of the vessels, at the extremity of the roots; that these mouths then contract, and by that contraction propel the sap upwards; that this contraction gradually follows the sap, pushing it up from the extremity of the root to the summit of the plant. In the mean time the mouths are receiving new sap, which in the same manner is pushed upwards †. Whether we suppose the contraction to take place precisely in this manner or not, we can scarcely deny that it must take place; but by what means it is impossible at present to say. The agents cannot precisely resemble the muscles of animals; because the whole tube, however cut or maimed, still retains its contracting power, and because the contraction

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* *Edin. Trans.* i.

† *Encycl. Meth. Phys. Veget.* p. 267.

is performed with equal readiness in every direction *. It is evident, however, that they must be the same in kind. Perhaps the particular structure of the vessels may fit them for their office. Does ring after ring contract its diameter? The contracting agents, whatever they are, seem to be excited to act by some stimulus communicated to them by the sap. This capacity of being excited to action is known in physiology by the name of *irritability*; and there are not wanting proofs that plants are possessed of it. It is well known that different parts of plants move when certain substances act upon them. Thus the flowers of many plants open at sunrise, and close again at night. Linnæus has given us a list of these plants. Des Fontaines has shewn that the stamina and antheræ of many plants exhibit distinct motions †. Dr Smith has observed, that the stamina of the barberries are thrown into motions when touched ‡. Roth has ascertained that the leaves of the drosera longifolia and rotundifolia have the same property. Mr Coulon, too, who has adopted the opinion that the motion of the sap in plants is produced by the contraction of vessels, has even made a number of experiments in order to shew this contraction. But the fact is, that every one has it in his power to make a decisive expe-

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* Mr Knight thinks it probable that the sap is propelled by the contraction and expansion of what is called by carpenters the *silver grain* of the wood, between the laminæ of which the vessels run. (*Phil. Trans.* 1801, p. 344.) By *silver grain* is meant those thin longitudinal fibres, diverging in every direction from the pith, and composed of the lymphatic vessels of Grew and Malpighi. I do not see how the contraction of these laminæ could propel the sap through the sap vessels, destitute as they are of valves, unless it were a contraction precisely similar to what Saussure supposed to take place in the sap vessels.

† *Mem. Par.* 1787.

‡ *Phil. Trans.* lxxviii.

riment. Simply cutting a plant, the *euphorbia peplis* for instance, in two places, so as to separate a portion of the stem from the rest, is a complete demonstration that the vessels actually do contract. For whoever makes the experiment, will find that the milky juice of that plant flows out at both ends so completely, that if afterwards we cut the portion of the stem in the middle, no juice whatever appears. Now it is impossible that these phenomena could take place without a contraction of the vessels; for the vessels in that part of the stem which has been detached cannot have been *more* than full; and their diameter is so small, that if it were to continue unaltered, the capillary attraction would be more than sufficient to retain their contents, and consequently not a drop would flow out. Since, therefore, the whole liquid escapes, it must be driven out forcibly, and consequently the vessels must contract.

It seems pretty plain, too, that the vessels are excited to contract by various stimuli; the experiments of Coulon and Saussure render this probable, and an observation of Dr Smith Barton makes it next to certain. He found that plants growing in water vegetated with much greater vigour, provided a little camphor was thrown into the water *.

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* *Ann. de Chim.* xxiii. 63.

SECT. V.

FUNCTIONS OF THE LEAVES DURING THE DAY.

It has been ascertained that the sap ascends to the leaves, that there it undergoes certain alterations, and is converted into another fluid called the *succus proprius*, or *peculiar juice*; which, like the blood in animals, is afterwards employed in forming the various substances found in plants. Now the changes which the sap undergoes in the leaves, provided we can trace them, must throw a great deal of light upon the nature of vegetation. These changes are produced in part during the day, in part during the night. As the functions of the leaves during the day are very different from what they are during the night, it will be proper to consider them separately. In the present Section, let us endeavour to trace the actions of the leaves during the day, reserving the consideration of their other functions to the next Section.

Peculiar juice formed by the leaves.

I. No sooner has the sap arrived at the leaves, than a great part of it is thrown off by evaporation.

Part of the sap transpires.

1. The quantity thus perspired bears a very great proportion to the moisture imbibed. Mr Woodward found that a sprig of mint in 77 days imbibed 2558 grains of water, and yet its weight was only increased 15 grains*; therefore it must have given out 2543 grains. Another branch, which weighed 127 grains, increased in weight 128, and it had imbibed 14190 grains. Another sprig,

Its quantity.

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* *Phil. Trans.* No. ccliii.

weighing 76 grains, growing in water mixed with earth, increased in weight 168 grains, and had imbibed 10731 grains of water. These experiments demonstrate the great quantity of matter which is constantly leaving the plant. Dr Hales found that a cabbage transmitted daily a quantity of moisture equal to about half its weight; and that a sun flower, three feet high, transmitted in a day 1 lb. 14 oz. avoirdupoise*. He shewed, that the quantity of transpiration in the same plant was proportional to the surface of the leaves, and that when the leaves were taken off, the transpiration nearly ceased †. By these observations, he demonstrated that the leaves are the organs of transpiration. He found, too, that the transpiration was nearly confined to the day, very little taking place during the night ‡; that it was much promoted by heat, and stopped by rain and frost §. And Millar ||, Guettard ¶, and Sennebier, have shewn that the transpiration is also very much promoted by sunshine.

The quantity of moisture imbibed by plants depends very much upon what they transpire: The reason is evident: when the vessels are once filled with sap, if none be carried off, no more can enter; and, of course, the quantity which enters must depend upon the quantity emitted.

Nature of the perspired matter.

2. In order to discover the nature of the transpired matter, Hales placed plants in large glass vessels, and by that means collected a quantity of it **. He found that it resembled pure water in every particular, except-

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* *Veget. Stat* i. 5. and 15. † Ibid. 30. ‡ Ibid. 5.
§ Ibid. 27. and 48. || Ibid. 22. ¶ *Mem. Par.* 1748.
** *Veget. Stat.* i. 49.

ing only that it sometimes had the odour of the plant. He remarked, too, as Guettard and Du Hamel did after him, that when kept for some time it putrefied, or at least acquired a stinking smell. Sennebier subjected a quantity of this liquid to a chemical analysis.

He collected 13030 grains of it from a vine during the months of May and June. After filtration he gradually evaporated the whole to dryness. There remained behind two grains of residuum. These two grains consisted of nearly ½ grain of carbonat of lime, $\frac{1}{12}$th grain of sulphat of lime, ¼ grain of matter soluble in water, and having the appearance of gum, and ½ grain of matter which was soluble in alcohol, and apparently resinous. He analysed 60768 grains of the same liquid, collected from the vine during the months of July and August. On evaporation he obtained 2⅛ grains of residuum, composed of ¾ grain of carbonat of lime, ¼ grain of sulphat of lime, ½ grain of mucilage, and ½ grain of resin. The liquid transpired by the *aster novæ Angliæ* afforded precisely the same ingredients *.

Proportion to the liquid absorbed.

3. Sennebier attempted to ascertain the proportion which the liquid transpired bore to the quantity of moisture imbibed by the plant. But it is easy to see that such experiments are liable to too great uncertainties to be depended on. His method was as follows: He plunged the thick end of the branch on which he made the experiment into a bottle of water, while the other end, containing all its leaves, was thrust into a very large glass globe. The apparatus was then exposed to the sunshine. The quantity imbibed was known exactly by the water which disappeared from the bottle, and

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* *Encyc. Method. Phys. Veget.* 287.

the quantity transpired was judged of by the liquid which condensed and trickled down the sides of the glass globe. The following TABLE exhibits the result of his experiments :

Plants.	Imbibed.	Perspired.	Time.
Peach	100 gr.	35 gr.	
Ditto	210	90	
Ditto	220	120	
Mint	200	90	2 days.
Ditto	575	120	10
Rasp	725	560	2
Ditto	1232	765	2
Peach	710	295	1
Apricot	210	180	1

In some of his experiments no liquid at all was condensed. Hence it is evident that the quantity of matter transpired cannot be deduced from these experiments. The mouth of the glass globe does not seem to have been accurately closed ; the air within it communicated with the external air ; consequently the quantity condensed must have depended entirely upon the state of the external air, the heat, &c.

4. The first great change, then, which takes place upon the sap after it arrives at the leaves, is the evaporation of a great part of it ; consequently what remains must be very different in its proportions from the sap. The leaves seem to have particular organs adapted for throwing off part of the sap by transpiration. For the experiments of Guettard *, Duhamel †, and Bonnet ‡.

Peculiar organ of transpiration.

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* *Mem. Par.* 1749. † *Physique des Arbres*, i. 158.

‡ *Traité des Feuilles* 1. *Mem.*

shew that it is performed chiefly by the upper surfaces of leaves, and may be nearly stopped altogether by varnishing the upper surface.

Why the leaves fall off.

The leaves of plants become gradually less and less fit for this transpiration; for Sennebier found that when all other things are equal, the transpiration is much greater in May than in September*. Hence the reason that the leaves are renewed annually. Their organs become gradually unfit for performing their functions, and therefore it is necessary to renew them. Those trees which retain their leaves during the winter, were found by Hales and succeeding physiologists to transpire less than others. It is now well known that these trees also renew their leaves.

Leaves absorb carbonic acid.

II. Leaves have also the property of absorbing carbonic acid gas from the atmosphere.

1. We are indebted for this very important discovery to the experiments of Dr Priestley. It has been long known that when a candle has been allowed to burn out in any quantity of air, no candle can afterwards be made to burn in it. In the year 1771 Dr Priestly made a sprig of mint vegetate for ten days in contact with a quantity of such air; after which he found that a candle would burn in it perfectly well†. This experiment he repeated frequently, and found that it was always attended with the same result. According to the opinion at that time universally received, that the burning of candles rendered air impure by communicating phlogiston to it, he concluded from it, that plants, while they vegetate, absorb phlogiston.

Carbonic acid gas was at that time supposed to con-

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[*] *Encyc. Meth. Veget.* 285.

[†] *On Air*, iii. 251.

tain phlogiston. It was natural, therefore, to suppose that it would afford nourishment to plants, since they had the property of absorbing phlogiston from the atmosphere. Dr Percival had published a set of experiments; by which he endeavoured to shew that this was actually the case.

These experiments induced Dr Priestley, in 1776, to consider the subject with more attention. But as, in all the experiments which he made, the plants confined in carbonic acid gas very soon died, he concluded that carbonic acid gas was not a food, but a poison to plants*. Mr Henry of Manchester was led, in 1784, probably by the contrariety of these results, to examine the subject. His experiments, which were published in the Manchester Transactions†, perfectly coincided with those of Dr Percival. For he found that carbonic acid gas, so far from killing plants, constantly promoted their growth and vigour. Meanwhile Mr Sennebier was occupied at Geneva with the same subject; and he published the result of his researches in his *Memoires Physico-Chymique* about the year 1780. His experiments shewed, in the clearest manner, that carbonic acid gas is used by plants as food. The same thing was supported by Ingenhousz in his second volume. The experiments of Saussure Junior, published in 1797, have at last put the subject beyond the reach of dispute. From a careful comparison of the experiments of these philosophers, it will not be difficult for us to discover the various phenomena, and to reconcile all the seeming contradictions which occur in them. The facts are as follows:

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* *On Air*, i. 100.

† ii. 341.

Plants do not vegetate unless that gas be present.

2. Mr Saussure has shewn that plants will not vegetate when totally deprived of carbonic acid gas. They vegetate indeed well enough in air which has been previously deprived of carbonic acid gas; but when a quantity of lime was put into the glass vessel which contained them, they no longer continued to grow, and the leaves in a few days fell off*. The air, when examined, was found to contain no carbonic acid gas. The reason of this phenomenon is, that plants (as we shall see afterwards) have the power of forming and giving out carbonic acid in certain circumstances; and this quantity is sufficient to continue their vegetation for a certain time. But if this new formed gas be also withdrawn, by quicklime for instance, which absorbs it the instant it appears, the leaves droop, and refuse to perform their functions. Carbonic acid gas, then, applied to the leaves of plants, is *essential* to vegetation.

Leaves emit oxygen gas

3. Dr Priestley, to whom we are indebted for many of the most important facts relative to vegetation, observed, in the year 1778, that plants, in certain circumstances, emitted oxygen gas†; and Ingenhousz very soon after discovered that this gas is emitted by the *leaves* of plants, and only when they are exposed to the bright light of day. His method was to plunge the leaves of different plants into vessels full of water, and then expose them to the sun, as Bonnet, who had observed the same phenomenon, though he had given a wrong explanation of it, had done before him. Bubbles of oxygen gas very soon detached themselves from the leaves, and were collected in an inverted glass vessel‡. He observed, too, that it was not a matter of

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* *Ann. de Chim.* xxiv. 145. 148.

† *On Air*, iii. 284.

‡ Ingenhousz *on Veget.* i. 15. &c.

indifference what kind of water was used. If the water, for instance, had been previously boiled, little or no oxygen gas escaped from the leaves; river water afforded but little gas; but pump water was the most productive of all *.

By decomposing carbonic acid.

4. Sennebier proved, that if the water be previously deprived of all its air by boiling, the leaves do not emit a particle of air; that those kinds of water which yield most air, contain in them the greatest quantity of carbonic acid gas; that leaves do not yield any oxygen when plunged in water totally destitute of carbonic acid gas; that they emit it abundantly when the water, rendered unproductive by boiling, is impregnated with carbonic acid gas; that the quantity of oxygen emitted, and even its purity, is proportional to the quantity of carbonic acid gas which the water contains; that water impregnated with carbonic acid gas gradually loses the property of affording oxygen gas with leaves; and that whenever this happens, all the carbonic acid gas has disappeared; and on adding more carbonic acid gas the property is renewed †. These experiments prove, in a most satisfactory manner, that the oxygen gas which the leaves of plants emit depends upon the presence of carbonic acid gas; that the leaves absorb carbonic acid gas, decompose it, give out the oxygen, and retain the carbon.

Only during the day.

5. We now see why plants will not vegetate without carbonic acid gas. They absorb it and decompose it; but this process goes on only when the plants are exposed to the light of day. Therefore we may conclude that the absorption and decomposition of carbo-

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* Ingenhousz *on Veget.* i. 83.

† *Encyc. Meth. Phys. Veget.* 181.

nic acid gas is confined to the day, and that light is an essential agent in the decomposition. Probably it is by its agency, or by its entering into combination with the oxygen, that this substance is enabled to assume the gaseous form, and to separate from the carbon.

If we reason from analogy, we shall conclude that during this process a quantity of caloric is necessary; and that therefore no increase of temperature takes place, but rather the contrary. This may be one reason why the operation takes place only during the day.

Plants this way acquire much carbon.

6. It is extremely probable that plants by this process acquire the greatest part of the carbonaceous matter which they contain; for if we compare the quantity of carbon contained in plants vegetating in the dark, where this process cannot go on, with the quantity which those plants contain which vegetate in the usual manner, we shall perceive a very conspicuous difference. Chaptal found that a byssus, which was vegetating in the dark, contained only $\frac{1}{80}$ of its weight of carbonaceous matter; but the same plant, after being made to vegetate in the light for 30 days, contained $\frac{1}{24}$ of its weight of carbonaceous matter *. Hassenfratz ascertained, that plants growing in the dark contain much more water, and much less carbon and hydrogen, than plants growing in the light. Sennebier analysed both with the same result. Plants growing in the dark yielded less hydrogen gas and oil: their resinous matter was to that of plants growing in the light as 2 to 5.5, and their moisture as 13 to 6; they contain even one-half less of fixed matters.

It is evident, however, that this absorption and de-

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* *Mem. Par.* 1786.

composition of carbonic acid gas does not depend upon the light alone. The nature of the sap has also its influence; for Hassenfratz found, that the quantity of carbon did not increase when plants vegetated in pure water. Here the sap seems to have wanted that part which combines with and retains the carbon; and which therefore is by far the most important part of the food of plants. Upon the discovery and mode of applying this substance, whatever it is, the improvements in agriculture must in a great measure depend.

If we consider the difference in the proportion of carbonaceous matter in plants vegetating in the dark, and in the usual manner, we can scarcely avoid concluding that the quantity of carbonic acid gas absorbed by plants is considerable. To form an estimate of it, would require a set of experiments performed in a very different manner from any hitherto made. The stems and branches of plants vegetating in a rich soil should be confined within a large glass globe, the inside of which ought to have no communication with the external air. A very small stream of carbonic acid gas should be made occasionally to flow into this globe, so as to supply the quantity that may appear necessary; and there should be a contrivance to carry off and examine the air within the globe when it increases beyond a certain quantity. Experiments conducted in this manner would probably throw a great deal of light upon this part of vegetation, and enable us to calculate the quantity of carbonic acid decomposed, and the quantity of oxygen emitted by plants; to compare these with the waste of oxygen by the respiration of animals and combustion, and to see whether or not they balance each other.

The decomposition performed by the parenchyma.

7. Sennebier has ascertained, that the decomposition of the carbonic acid takes place in the parenchyma. He found, that the epidermis of a leaf would, when separated, give out no air, neither would the nerves in the same circumstances; but upon trying the parenchyma, thus separated from its epidermis and part of its nerves, it continued to give out oxygen as before *. He remarked also, that every thing else being equal, the quantity of oxygen emitted, and consequently of carbonic acid decomposed, is proportional to the thickness of the leaf; and this thickness depends upon the quantity of parenchyma.

That the decomposition is performed by peculiar organs, is evident from an experiment of Ingenhousz. Leaves cut into small pieces continued to give out oxygen as before; but leaves pounded in a mortar lost the property entirely. In the first state, the peculiar structure remained; in the other, it was destroyed. Certain experiments of Count Rumford, indeed, are totally incompatible with this conclusion; and they will naturally occur to the reader as an unsurmountable objection. He found, that dried leaves, black poplar, fibres of raw silk, and even glass, when plunged into water, gave out oxygen gas by the light of the sun. But when Sennebier repeated these experiments, not one of them would succeed †. The Count must have been misled by something which he has not mentioned.

Such are the operations performed by the leaves during the day. They seem in some measure to depend upon the action of light; for they never take place ex-

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* *Encyc. Method. Physiol. Veget.* 180.

† *Ann. de Chim.* i. 115.

cept when the leaves are exposed to the influence of light.

Green colour produced by the light.

III. The green colour of plants is owing entirely to their vegetating in the light; for when they vegetate in the dark they are white; and when exposed to the light they acquire a green colour in a very short time, in whatsoever situation they are placed, even though plunged in water, provided always that oxygen be present; for Mr Gough has shewn, that light without oxygen has not the power of producing the green colour *.

Sennebier has observed, that when plants are made to vegetate in the dark, their etiolation is much diminished by mixing a little hydrogen gas with the air that surrounds them †. Ingenhousz had already remarked, that when a little hydrogen gas is added to the air in which plants vegetate, even in the light, it renders their verdure deeper ‡: and he seems to think also, that he has proved by experiments, that plants absorb hydrogen gas in these circumstances §. Mr Humbolt has observed, that the poa annua and compressa, plantago lanceolata, trifolium arvense, cheiranthus cheiri, lichen verticillatus, and several other plants which grow in the galleries of mines, retain their green colour even in the dark, and that in these cases the air around them contains a quantity of hydrogen gas. This philosopher concludes, from his observations, that the white colour of etiolated plants is occasioned by their retaining an unusual proportion of oxygen, and that this is prevented by surrounding them with hydrogen gas. This may perhaps be true in certain cases; but the experiments

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* *Manch. Mem.* iv. 501.

† *Encyc. Meth. Physiol. Veget.* 77.

‡ *Ann. de Chim.* iii. 57.

§ Ibid. p. 61.

of Mr Gough, mentioned above, are sufficient to prove that the retention of oxygen is not the only difference between green and etiolated plants *.

Thus it has been seen, that when the sap arrives at the leaves, great part is thrown off by evaporation, and that the nature of the remainder is considerably altered by the addition of a quantity of carbon: but these are by no means all the alterations produced upon the sap in the leaves.

SECT. VI.

FUNCTIONS OF THE LEAVES DURING THE NIGHT.

During the night

During the day, then, the leaves of plants exhale moisture and oxygen gas, and absorb carbonic acid gas; let us now endeavour to trace the operations which they perform during the night.

Leaves absorb oxygen,

1. Plants will not vegetate unless atmospheric air or oxygen gas have access to their leaves. This was rendered probable by those philosophers who, about the end of the 17th century, turned their attention particularly towards the physical properties of the air. But Dr Ingenhousz was perhaps the first of the modern chemists who put it beyond doubt. He found that carbonic acid gas, azotic, and hydrogen gas, destroyed

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* Plants of a white colour, from vegetating in the dark, are called *etiolated*, from a French word which signifies a *star*, as if they grew by *star light*.

plants altogether, unless they were mixed with atmospheric air or oxygen gas. He found also, that plants grew very well in oxygen gas and in atmospheric air*. These experiments are sufficient to shew that oxygen gas is necessary to vegetation. The leaves of plants seem to absorb it; and most probably this absorption takes place only in the night. We know, at least, that in germination light is injurious to the absorption of oxygen gas; and therefore it is probable that this is the case also in vegetation.

And water,

2. The leaves of plants not only absorb oxygen gas, but water also. This had been suspected in all ages: the great effect which dew, slight showers, and even wetting the leaves of plants, have in recruiting their strength, and making them vegetate with vigour, are so many prooofs that the leaves imbibe moisture from the atmosphere. Hales rendered this still more probable, by observing, that plants increase considerably in weight when the atmosphere is moist; and Mr Bonnet put the matter beyond doubt in his *Researches concerning the Use of the Leaves*. He shewed that leaves continue to live for weeks when one of their surfaces is applied to water; and that they not only vegetate themselves, but even imbibe enough of water to support the vegetation of a whole branch, and the leaves belonging to it. He discovered also, that the two surfaces of leaves differ very considerably in their power of imbibing moisture; that in trees and shrubs, the under surface possesses almost the whole of the property, while the contrary holds in many of the other plants; the kidney bean for instance.

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* Ingenhousz, ii. passim.

These facts prove, not only that the leaves of plants have the power of absorbing moisture, but also that the absorption is performed by very different organs from those which emit moisture ; for these organs lie on different sides of the leaf. If we consider that it is only during the night that the leaves of plants are moistened with dew, we can scarcely avoid concluding, that, except in particular cases, it is during the night that plants imbibe almost all the moisture which they do imbibe.

And emit carbonic acid gas.

3. During the night the leaves of plants emit carbonic acid gas. This fact was first demonstrated by Dr Ingenhousz *, and it has been since confirmed by every philosopher who has attended to the subject.

Thus we have seen that the leaves of plants perform very different operations at different times. During the day they are giving out moisture, absorbing carbonic acid gas, and emitting oxygen gas ; during the night, on the contrary, they are absorbing moisture, giving out carbonic acid gas, and absorbing oxygen gas.

Sap altered by these processes.

4. Whether the emission of carbonic acid be occasioned by the combination of the oxygen absorbed with the carbon of the sap, or by the decomposition of water, has not been ascertained. What gives probability to the first opinion is, that the absorption of oxygen and the emission of carbonic acid take place at the same time. It is extremely probable that there is also a decomposition of water going on in the sap. But if such a decomposition takes place, it depends in a good measure upon the quantity of oxygen gas absorbed ; for Dr Ingenhousz found, that when plants are confined

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* On *Vegetables*, i. 47. and ii. passim.

in oxygen gas, they emit more carbonic acid gas than when they are confined in common air *.

To describe in what manner these decompositions take place, is impossible; because we neither know precisely the substances into which the sap has been converted by the operations performed during the day, nor the new substances formed by the operations of the night. We only see the elementary substances which are added and subtracted; which is far from being sufficient to give us precise notions concerning the chemical changes and the affinities by which these changes are produced. We have reason, however, to conclude, that during the day the carbon of the sap is increased, and that during the night the hydrogen and oxygen are increased; but the precise new substances formed are unknown to us. Nor let any one suppose that the increase of the hydrogen and of the oxygen of the sap is the same thing as the addition of a quantity of water. Far from it. The substances into which the sap is converted have been enumerated in the last Chapter; almost all of them consist chiefly of carbon, hydrogen, and oxygen, and yet none of them has the smallest resemblance to water. In water, oxygen and hydrogen are already combined together in a certain proportion; and this combination must be broken before these elementary bodies can enter into those triple compounds with carbon, of which a great part of the vegetable products consist. We have not the smallest conception of the manner in which these triple combinations are formed, and as little of the manner in which the bodies which compose vegetable substances are combined

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* Ingenhousz, ii.

together. The combination may, for any thing we know to the contrary, be very complicated, though it consists only of three ingredients; and analogy leads us to suppose that it actually is very complicated: for in chemistry it may be considered as a truth, to which at present few or no exceptions are known, that bodies are decomposed with a facility inversely as the simplicity of their composition; that is to say, that those bodies which consist of the fewest ingredients are most difficultly decomposed, and that those which are formed of many ingredients are decomposed with the greatest facility.

Neither let any one suppose that the absorption of carbonic acid gas during the day is balanced by the quantity emitted during the night; and that therefore there is no increase of carbon: for Ingenhousz has shewn that the quantity of oxygen gas emitted during the day is much greater than the carbonic acid gas emitted during the night; and that in favourable circumstances, the quantity of oxygen gas in the air surrounding plants is very much increased, and the carbonic acid gas diminished; so much so, that both Dr Priestley and Dr Ingenhousz found, that air which had been spoiled by a lighted candle, or by animals, was rendered as good as ever by plants. Now we know, that combustion and respiration diminish the oxygen gas, and add carbonic acid gas to air; therefore vegetation, which restores the purity of air altered by these processes, must increase the oxygen, and diminish the carbonic acid gas of that air; consequently the quantity of carbonic acid gas absorbed by plants during the day is greater than the quantity emitted by them during the night, and of course the carbon of the sap is increased in the leaves.

It is true, that when plants are made to vegetate for a number of days in a given quantity of air, its ingredients are not found to be altered. Thus Hassenfratz ascertained that the air, in which young chesnuts vegetated for a number of days together, was not altered in its properties, whether the chesnuts were vegetating in water or in earth *. And Saussure Junior proved, that pease growing for ten days in water did not alter the surrounding air †. But this is precisely what ought to be the case, and what must take place, provided the conclusions which I have drawn be just. For if plants only omit oxygen gas by absorbing and decomposing carbonic acid gas, it is evident, that unless carbonic acid gas be present, they can emit no oxygen gas; and whenever they have decomposed all the carbonic acid gas contained in a given quantity of air, we have no longer any reason to look for their emitting any more oxygen gas; and if the quantity of carbonic acid gas emitted during the night be smaller than that absorbed during the day, it is evident, that during the day the plant will constantly decompose all the acid which had been formed during the night. By these processes, the mutual changes of day and night compensate each other; and they are prevented from more than compensating cach other by the forced state of the plant. It is probable, that when only part of a plant is made to vegetate in this forced state, some *carbonated sap* (if I may be allowed the expression) is supplied by the rest of the plant; and that therefore the quantity of carbonic acid gas emitted during the night may bear a nearer proportion to that emitted in a state of nature

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* *Ann. de Chim.* xiii. 325.

† Ibid. xxiv. 139.

than that of the absorption of fixed air can possibly do. And probably, even when the whole plant is thus confined, the nightly process goes on for a certain time at the expence of the carbon already in the sap; for Hassenfratz found, that in these cases the quantity of carbon in the plant, after it had vegetated for some time in the dark, was less than it had been when it began to vegetate *. This is the reason that plants growing in the dark, when confined, absorb all the oxygen gas, and emit an equal quantity of carbonic acid gas: and whenever this has happened, they die; because then neither the daily nor nightly processes can go on.

SECT. VII.

OF THE PECULIAR JUICES OF PLANTS.

By these changes which go on in the leaves, the nature of the sap is altogether changed. It is now converted into what is called the *peculiar juice*, and is fit for being assimilated to the different parts of the plant, and for being employed in the formation of those secretions which are necessary for the purposes of the vegetable economy.

Leaves the digesting organs of plants.

The leaves, therefore, may be considered as the digesting organs of plants, and as equivalent in some measure to the stomach and lungs of animals. The leaves consequently are not mere ornaments; they are the most

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* *Ann. de Chim.* xiii. 188.

important parts of the plant. Accordingly we find, that whenever we strip a plant of its leaves, we strip it entirely of its vegetating powers till new leaves are formed. It is well known, that when the leaves of plants are destroyed by insects, they vegetate no longer, and that their fruit never makes any farther progress in ripening, but decays and dries up. Even in germination no progress is made in the growth of the stem till the seed leaves appear. As much food indeed is laid up in the cotyledons as advances the plant to a certain state; the root is prepared, and made ready to perform its functions; but the sap which it imbibes must be first carried to the seed leaves, and digested there, before it be proper for forming the plumula into a stem. Accordingly if the seed leaves are cut off, the plant refuses to vegetate.

How they are produced.

It will be very natural to ask, If this be true, how come the leaves themselves to be produced? Even if no answer could be given to this question, it could not overturn a single fact which has been mentioned, nor affect a single conclusion as far as it has been fairly deduced from these facts. We know that the leaves exist long before they appear; they have been traced even five years back. They are completely formed in the bud, and fairly rolled up for evolution, many months before that spring in which they expand. We know, too, that if we take a bud, and plant it properly, it vegetates, forms to itself a root, and becomes a complete plant. It will not be said, surely, that in this case the bud imbibes nourishment from the earth; for it has to form a root before it can obtain nourishment in that manner; and this root cannot be formed without nourishment. Is not this a demonstration that the bud contains, al-

Chap. II.

ready laid up in itself, a sufficient quantity of nourishment, not only to develope its own organs, but also to form new ones. This I consider as a sufficient answer to the objection. During the summer, the plant lays up a sufficient quantity of nourishment in each bud, and this nourishment is afterwards employed in developing the leaves. This is the reason that the leaves make their appearance, and that they grow during the winter, when the plant is deprived of its organs of digestion.

Hence we see why the branch of a vine, if it be introduced into a hot-house during the winter, puts forth leaves and vegetates with vigour, while every other part of the plant gives no signs of life. Hence also the reason that the inoculation of plants succeeds. Hence also the cause of another well-known phenomenon: The sap flows out of trees very readily in spring before the leaves appear, but after that the bleeding ceases altogether. It is evident that there can be scarcely any circulation of sap before the leaves appear; for as there is no outlet, when the vessels are once full they can admit no more. It appears, however, from the bleeding, that the roots are capable of imbibing, and the vessels of circulating, the sap with vigour. Accordingly, whenever there is an outlet, they perform their functions as usual, and the tree bleeds; that is, they send up a quantity of sap to be digested as usual: but as there are no digesting organs, it flows out, and the tree receives no injury, because the sap that flows out would not have been imbibed at all, had it not been for the artificial opening. But when the digestive organs appear, the tree will not bleed; because these organs require all the sap, and it is constantly flowing to them.

Absolutely necessary.

If a tree be deprived of its leaves, new leaves make their appearance, because they are already prepared for that purpose. But what would be the consequence if a tree were deprived of its leaves and of all its buds for five years back? That plants do not vegetate without leaves, is evident from an experiment of Duhamel. He stript the bark off a tree in ringlets, so as to leave five or six rings of it at some distance from each other, with no bark in the intervals. Some of these rings had buds and leaves; these increased considerably in size; but one ring which had none of these remained for years unaltered. Mr Knight found, that a shoot of the vine, when deprived of its leaves, died altogether [*].

Form the peculiar juice,

The *succus proprius*, or *peculiar juice* of plants, may be considered as analagous to the blood of animals. It is the food altered by digestion, and rendered fit for being assimilated and converted into a part of the plant itself, by the subsequent processes of vegetation. That it flows from the leaves of the plant towards the roots, appears from this circumstance, that when we make an incision into a plant, into whatever position we put it, much more of the succus proprius flows from that side of the wound which is next the leaves and branches, than from the other side: and this happens even though the leaves and branches be held undermost [†]. When a ligature is tied about a plant, a swelling appears above, but not below the ligature.

Which flows from the leaves

In vessels.

The vessels containing the peculiar juice have been traced by Mr Knight from the leaves into the cortical layers of the inner bark [‡]. Hedwig, who has examined

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[*] *Phil. Trans.* 1801, p. 338.

[†] Bell, *Manch. Mem.* ii. 402.

[‡] *Phil. Trans.* 1801, p. 337.

the vessels of plants with very great care, seems to consider them as of the same structure with the tracheæ; but Mr Knight is of a different opinion. It appears evidently, from the experiments of this last gentleman, that they communicate with no part of the plant which is situated at a greater distance from the root than the leaf from which they themselves originate. For when two circular incisions are made through the bark of a branch above and below a leaf, and at some distance from it, only that part of the portion confined between the two incisions which is situated below the leaf increases in size.

Its properties.

The peculiar juice is easily known by its colour and its consistence. In some plants it is green, in some red, in many milky. It cannot be doubted that its motion in the vessels is performed in the same way as that of the sap.

If we had any method of obtaining this peculiar juice in a state of purity, the analysis of it would throw a great deal of light upon vegetation; but this is scarce possible, as we cannot extract it without dividing at the same time the vessels which contain the sap. In many cases, however, the peculiar juice may be known by its colour, and then its analysis may be performed with an approach towards accuracy. The experiments made on such juices have proved, as might have been expected, that they differ very considerably from each other, and that every plant has a juice peculiar to itself. Hence it follows, that the processes which go on in the leaves of plants must differ at least in degree, and that we have no right to transfer the conclusions deduced from experiments on one species of plants to those of another species. It is even probable, that the processes in different plants are not the same in kind; for it is not reasonable to suppose, that the phenomena of vegetation in an agaric or a boletus are precisely the same as those which take place in trees and in larger vegetables, on which alone experiments have hitherto been made.

Contains vegetable fibre.

To attempt any general account of the ingredients of the peculiar juice of plants, is at present impossible. We may conclude, however, from the experiments of Chaptal, that it contains the *vegetable fibre* of wood, either ready formed, or very nearly so; just as the blood in animals contains a substance which bears a strong resemblance to the muscular fibres.

When oxy-muriatic acid was poured into the peculiar juice of the euphorbia, which in all the species of that singular genus is of a milky colour and consistency, a very copious white precipitate fell down. This powder, when washed and dried, had the appearance of fine starch, and was not altered by keeping. It was neither affected by water nor alkalies. Alcohol, assisted by heat, dissolved two thirds of it; which were again precipitated by water, and had all the properties of resin. The remaining third part possessed the properties of the *woody fibre*. Mr Chaptal tried the same experiment on the juices of a great number of other plants, and he constantly found that oxy-muriatic acid precipitated from them *woody fibre*. The seeds of plants exhibited exactly the same phenomenon; and a greater quantity of woody fibre was obtained from them than from an equal portion of the juices of plants *. These experiments are sufficient to shew that the proper juices of plants contain their nourishment ready prepared, nearly

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* *Ann. de Chim.* xxi. 285.

in the state in which it exists in the seed for the use of the young embryo.

The peculiar juices of plants, then, contain more carbon, hydrogen, and oxygen, and less water, and probably lime also, than the sap. They are conveyed to every part of the plant; and all the substances which we find in plants, and even the organs themselves, by which they perform their functions, are formed from them. But the thickest veil covers the whole of these processes; and so far have philosophers hitherto been from removing this veil, that they have not even been able to approach it. All these operations, indeed, are evidently chemical decompositions and combinations; but we neither know what these decompositions and combinations are, nor the instruments in which they take place, nor the agents by which they are regulated.

SECT. VIII.

OF THE DECAY OF PLANTS.

Plants decay and die.

SUCH, as far as I am acquainted with them, are the changes produced by vegetation. But plants do not continue to vegetate for ever; sooner or later they decay, and wither, and rot, and are totally decomposed. This change indeeed does not happen to all plants at the end of the same time. Some live only for a single season, or even for a shorter period; others live two seasons, others three, others a hundred or more; and there are some plants which continue to vegetate for a thousand years. But sooner or later they all cease to live;

and then those very chemical and mechanical powers which had promoted vegetation combine to destroy the remains of the plant. Now, What is the cause of this change? Why do plants die?

This question can only be answered by examining with some care what it is which constitutes the *life* of plants; for it is evident, that if we can discover what that is which constitutes the life of a plant, it cannot be difficult to discover what constitutes its death.

Phenomena of vegetable life

Now the phenomena of vegetable life are in general *vegetation*. As long as a plant continues to vegetate, we say that it lives; when it ceases to vegetate, we conclude that it is dead.

The life of vegetables, however, is not so intimately connected with the phenomena of vegetation that they cannot be separated. Many seeds may be kept for years without giving any symptom of vegetation; yet if they vegetate when put into the earth, we say that they possess life; and if we would speak accurately, we must say also that they possessed life even before they were put into the earth: for it would be absurd to suppose that the seed *obtained* life merely by being put into the earth. In like manner, many plants decay, and give no symptoms of vegetation during winter; yet if they vegetate when the mild temperature of spring affects them, we consider them as having lived all winter. The life of plants, then, and the phenomena of vegetation, are not precisely the same thing; for the one may be separated from the other, and we can even suppose the one to exist without the other. Nay, what is more, we can, in many cases, *decide*, without hesitation, that a vegetable is not dead, even when no vegetation appears; and the proof which we have for its life is, that it *remains unaltered;* for we know that when a vegetable is dead, it soon changes its appearance, and falls into decay.

Thus it appears that the *life* of a vegetable consists in two things: 1. In remaining unaltered, when circumstances are unfavourable to vegetation; 2. In exhibiting the phenomena of vegetation when circumstances are favourable. When neither of these two things happens, we say that a vegetable is dead.

Owing to a vegetative principle.

The phenomena of vegetation have been enumerated above. They consist in the formation or expansion of the organs of the plant, in the taking in of nourishment, in carrying it to the leaves, in digesting it, in distributing it through the plant, in augmenting the bulk of the plant, in repairing decayed parts, in forming new organs when they are necessary, in producing seeds capable of being converted into plants similar to the parent. The *cause* of these phenomena, whatever it may be, is the *cause* also of *vegetable life*, and may be distinguished by the name of the *vegetative principle*. But an enquiry into the nature of this principle belongs to the science of *physiology*, and would be foreign to the nature of this Work.

Death of plants.

The death of plants, if we can judge from the phenomena, is owing to the organs becoming at last altogether unfit for performing their functions, and incapable of being repaired by any of the powers which the vegetative principle possesses. The changes which vegetable substances undergo after death come now to be examined. They shall form the subject of the ensuing Chapter.

CHAP. III.

OF THE DECOMPOSITION OF VEGETABLE SUBSTANCES.

Vegetable decompositions.

NOT only entire plants undergo decomposition after death, but certain vegetable substances also, whenever they are mixed together, and placed in proper circumstances, mutually decompose each other, and new compound substances are produced. These mutual decompositions, indeed, are naturally to be expected: for as all vegetable substances are composed of several ingredients, differing in the strength of their affinity for each other, it is to be supposed that, when two such substances are mixed together, the divellent affinities will, in many cases, prove stronger than the quiescent; and therefore decomposition, and the formation of new compounds, must take place: just as happens when the acetite of lead and sulphat of potass are mixed together.

These mutual decompositions of vegetable substances are by no means so easily traced, or so readily explained, as the mutual decompositions of neutral salts; partly on account of the number of substances, whose affinities for each other are brought into action, and partly because we are ignorant of the manner in which the ingredients of vegetable substances are mutually combined.

Chemists have agreed to give these mutual decompositions which take place in vegetable substances the name

Called FERMENTATION.

f *fermentation* ; a word first introduced into chemistry y Van Helmont[*] ; and the new substances produced hey have called the *products* of fermentation. All the henomena of fermentation lay for many years conceal-l in the completest darkness, and no chemist was bold nough to hazard even an attempt to explain them. hey were employed, however, and without hesitation o, in the explanation of other phenomena ; as if giing to one process the name of another of which we re equally ignorant, could, in reality, add any thing our knowledge. The darkness which enveloped these henomena has lately begun to disperse ; but they are ill surrounded with a very thick mist ; and we must e much better acquainted with the composition of veetable substances, and the mutual affinities of their inredients, than we are at present, before we can explain em in a satisfactory manner.

Species.

The vegetable fermentations or decompositions may e arranged under five heads : namely, that which pro-uces *bread* ; that which produces *wine* ; that which roduces *beer* ; that which produces *acetous acid* or *vi-egar* ; and the *putrefactive* fermentation, or that which roduces the spontaneous decomposition of decayed veetables. These shall be the subject of the five follow-g Sections. In order to avoid long titles, I shall give the first three Sections the name of the new substan-s produced by the fermentation.

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[*] Stahl, *Fundament. Chem.* i. 124.

SECT. I.

OF BREAD.

Discovery of bread.

SIMPLE as the manufacture of bread may appear to us who have been always accustomed to consider it as a common process, its discovery was probably the work of ages, and the result of the united efforts of men, whose sagacity, had they lived in a more fortunate period of society, would have rendered them the rivals of Aristotle or of Newton.

The method of making bread similar to ours was known in the East at a very early period; but neither the precise time of the discovery, nor the name of the person who published it to the world, has been preserved. We are certain that the Jews were acquainted with it in the time of Moses: for in Exodus* we find a prohibition to use leavened bread during the celebration of the passover. It does not appear, however, to have been known to Abraham; for we hear in his history of cakes frequently, but nothing of leaven. Egypt, both from the nature of the soil and the early period at which it was civilized, bids fairest for the discovery of making bread. It can scarcely be doubted that the Jews learned the art from the Egyptians. The Greeks assure us, that they were taught the art of making bread by the god Pan. We learn from Homer that it was known during the Trojan war†. The Ro-

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* Chap. xii v. 15.

† Iliad ix. 216

mans were ignorant of the method of making bread till the year 580, after the building of Rome, or 200 years before the commencement of the Christian era*. Since that period the art has never been unknown in the south of Europe; but it made its way to the north very slowly, and even at present in many northern countries fermented bread is but very seldom used.

Substances which make bread.

The only substance well adapted for making bread, I mean *loaf bread*, is wheat flour, which is composed of four ingredients; namely, gluten, starch, albumen, and a *sweet mucous matter*, which possesses nearly the properties of sugar, and which is probably a mixture of sugar and mucilage. It is to the gluten that wheat flour owes its superiority to every other as the basis of bread. Indeed there are only two other substances at present known of which loaf bread can be made; these are *rye* and *potatoes*. The rye loaf is by no means so well raised as the wheat loaf; and potatoes will not make bread at all without particular management. Potatoes, previously boiled and reduced to a very fine tough paste by a rolling pin, must be mixed with an equal weight of potato starch. This mixture, baked in the usual way, makes a very white, well raised, pleasant bread. We are indebted for the process to Mr Permentier. Barley-meal perhaps might be substituted for starch.

Method of baking bread.

The baking of bread consists in mixing wheat flour with water, and forming it into a paste. The average proportion of these is two parts of water to three of flour. But this proportion varies considerably, according to the age and the quality of the flour. In general,

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* Pliny, lib. xviii. cap. 11.

the older and the better the flour is, the greater is the quantity of water required. If the paste, after being thus formed, be allowed to remain for some time, its ingredients gradually act upon each other, and the paste acquires new properties. It gets a disagreeable sour taste, and a quantity of gas (probably carbonic acid gas) is evolved. In short, the paste ferments[*]. These changes do not take place without water; that liquid, therefore, is a necessary agent. Possibly it is decomposed by the action of the starch upon it; for when starch is diluted with water, it gradually becomes sour. The gluten, too, is altered, either by the action of the water on it, or of the starch; for if we examine the paste after it has undergone fermentation, the gluten is no longer to be found. If paste, after standing for a sufficient time to ferment, be baked in the usual way, it forms a loaf full of eyes like our bread, but of a taste so sour and unpleasant that it cannot be eaten. If a small quantity of this old paste, or *leaven* as it is called, be mixed with new made paste, the whole begins to ferment in a short time; a quantity of gas is evolved; but the glutinous part of the flour renders the paste so tough that the gas cannot escape; it therefore causes the paste to swell in every direction: and if it be now baked into loaves, the immense number of air bubbles imprisoned in every part renders the bread quite full of eyes, and very light. If the precise quantity of leaven necessary to produce the fermentation, and no more, has been used, the bread is sufficiently light, and has no unpleasant taste; but if too much leaven be employed,

Ferments.

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[*] It was from this process that Van Helmont transferred the word *fermentation* into chemistry.

the bread has a bad taste; if too little, the fermentation does not come on, and the bread is too compact and heavy. To make good bread with leaven therefore is difficult.

Fermentation promoted by barm.

The ancient Gauls had another method of fermenting bread. They formed their paste in the usual way; and instead of leaven, mixed with it a little of the *barm* which collects on the surface of fermenting beer*. This mixture produced as complete and as speedy a fermentation as leaven; and it had the great advantage of not being apt to spoil the taste of the bread. About the end of the 17th century, the bakers in Paris began to introduce this practice into their processes. The practice was discovered, and exclaimed against; the faculty of medicine, in 1688, declared it prejudicial to health; and it was not till after a long time that the bakers succeeded in convincing the public that bread baked with *barm* is superior to bread baked with leaven. In this country the bread has for these many years been fermented with barm.

Analysis of barm.

What is this barm which produces these effects? Mr Henry of Manchester has proved, by a number of very interesting experiments, that carbonic acid is capable of being employed in many cases with success as a substitute for barm †. But the analysis of Mr Westrum has demonstrated, that the barm which collects on the surface of beer is of a much more complicated nature. That celebrated chemist obtained from 15360 parts of good barm the following substances:

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* Pliny, lib. xviii. cap. 7.

† *Manchester Memoirs*, ii 162.

15	carbonic acid
10	acetous acid
45	malic acid
240	alcohol
120	extract
240	mucilage
315	sugar
480	gluten
13595	water
15060	

Besides 69 parts of lime, 13 potass, some mucous acid, and traces of phosphoric acid and silica *.

But all these ingredients are not essential to barm, as Westrum has very properly observed. It has been customary with the bakers of Paris to bring their barm from Flanders and Picardy in a state of dryness. When skimmed off the beer, it is put into sacks, and the moisture allowed to drop out; then these sacks are subjected to a strong pressure, and when the barm is dry it is made up into balls †. Now this process must separate the water, carbonic acid, acetous acid, and alcohol; yet this barm, when again moistened, ferments bread equally well with new barm; therefore the presence of these bodies is not essential. Westrum ascertained, that the extract, mucilage, sugar, and malic acid, are incapable of producing fermentation; that barm, deprived of its gluten by filtration, loses the property of exciting fermentation in beer; that the gluten of wheat is capable alone of exciting a fermentation; and that gluten, mixed with a vegetable acid, answers all the purposes of a

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* Crell's *Annals*, 1796, i. 13.

† *Encyc. Method. Art. et Met.* i. 249.

ferment. Hence it follows, that these bodies alone are essential to barm. But leven is precisely such a compound.

Heat of the oven.

After the bread has fermented, and is properly raised, it is put into the oven previously heated, and allowed to remain till it be baked. The mean heat of an oven, as ascertained by Mr Tillet, is 448 [*]. The bakers do not use a thermometer; but they judge that the oven has arrived at the proper heat when flour thrown on the floor of it becomes black very soon without taking fire. We see, from Tillet's experiment, that this happens at the heat of 448°.

Loss of weight sustained in it.

When the bread is taken out of the oven, it is found to be lighter than when put in; as might naturally have been expected, from the evaporation of moisture which must have taken place at that temperature. Mr Tillet, and the other commissioners who were appointed to examine this subject in consequence of a petition from the bakers of Paris, found that a loaf, which weighed before it was put into the oven 4.625 lbs. after being taken out baked, weighed, at an average, only 3.813 lbs. or 0.812 lb. less than the paste. Consequently 100 parts of paste lose, at an average, 17.34 parts, or somewhat more than $\frac{1}{5}$th by baking [†]. They found, however, that this loss of weight was by no means uniform, even with respect to those loaves which were in the oven at the same time, of the same form, and in the same place, and which were put in and taken out at the same instant. The greatest difference in these circumstances amounted to .2889, or 7.5 parts in the hundred, which is about $\frac{1}{13}$th of the whole. This difference is

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[*] *Encyc. Method. Art. et Metiers*, i. 275.

[†] Ibid.

very considerable, and it is not easy to say to what it is owing. It is evident, that if the paste has not all the same degree of moisture, and if the barm be not accurately mixed through the whole, if the fermentation of the whole be not precisely the same, that these differences must take place. Now it is needless to observe how difficult it is to perform all this completely. The French commissioners found, as might indeed have been expected, that, other things being equal, the loss of weight sustained is proportional to the extent of surface of the loaf, and to the length of time that it remains in the oven; that is to say, the smaller the extent of the external surface, or, which is the same thing, the nearer the loaf approaches to a globular figure, the smaller is the loss of weight which it sustains; and the longer it continues in the oven, the greater is the loss of weight which it sustains. Thus a loaf which weighed exactly 4 lbs. when newly taken out of the oven, being replaced as soon as weighed, lost, in ten minutes, .125 lb. of its weight, and in ten minutes more it again lost .0625 lb.*.

Loaves are heaviest when just taken out of the oven; they gradually lose part of their weight, at least if not kept in a damp place, or wrapt round with a wet cloth†. Thus Mr Tillet found that a loaf of 4 lbs. after being kept for a week, wanted .3125, or nearly $\frac{1}{13}$th of its original weight‡.

When bread is newly taken out of the oven, it has a

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[*] *Encyc. Method.* art. i. 270.

[†] This is an excellent method of preserving bread fresh, and free from mould, for a long time.

[‡] *Encyc. Method.* art. i. 270.

Properties of bread.

peculiar, and rather pleasant smell, which it loses by keeping, unless its moisture be preserved by wrapping it round with a wet cloth; as it does also the peculiar taste by which new bread is distinguished. This shews us, that the bread undergoes chemical changes; but what these changes are, or what the peculiar substance is to which the odour of bread is owing, is not known.

Bread differs very completely from the flour of which it is made, for none of the ingredients of the flour can now be discovered in it. The only chemist who has attempted an analysis of bread is Mr Geoffroy. He found that 100 parts of bread contained the following ingredients:

24.735	water
32.030	gelatinous matter, extracted by boiling water
39.843	residuum insoluble in water
96.608	
3.392	loss
100.	

But this analysis, which was published in the Memoirs of the French Academy for the year 1732, was made at a time when the infant state of the science of chemistry did not admit of any thing like accuracy.

SECT. II.

OF WINE.

There is a considerable number of ripe fruits from which a sweet liquor may be expressed, having at the

Fruits affording wine.

same time a certain degree of acidity. Of such fruits we have in this country the apple, the cherry, the gooseberry, the currant, &c. but by far the most valuable of these fruits is the *grape*, which grows luxuriantly in the southern parts of Europe. From grapes, fully ripe, may be expressed a liquid of a sweet taste, to which the name of *must* has been given. This liquid is composed almost entirely of five ingredients; namely, *water*, *sugar*, *jelly*, *extract*, and *tartarous* acid partly saturated with potass. The quantity of sugar which grapes fully ripe contain is very considerable; it may be obtained in crystals by evaporating must to the consistence of syrup, separating the tartar which precipitates during the evaporation, and then setting the must aside for some months. The crystals of sugar are gradually formed.

Must

Undergoes the vinous fermentation:

When must is put into the temperature of about 70°, the different ingredients begin to act upon each other, and what is called *vinous fermentation* commences. The phenomena of this fermentation are an intestine motion in the liquid; it becomes thick and muddy, its temperature increases, and carbonic acid gas is evolved. In a few days the fermentation ceases, the thick part subsides to the bottom or rises to the surface, the liquid becomes clear, it has lost its saccharine taste, and assumed a new one; its specific gravity is diminished; and, in short, it has become the liquid well known under the name of *wine*.

Now what is the cause of this fermentation? what are the substances which mutually decompose each other? and what is the nature of the new substance formed?

These changes are produced altogether by the mutual action of the substances contained in must; for ey take place equally well, and wine is formed equally ell in close vessels as in the open air [*].

For which water,

If the *must* be evaporated to the consistency of a ick syrup, or to a *rob*, as the elder chemists termed , the fermentation will not commence, though the pro- er temperature, and every thing else necessary to pro- uce fermentation, be present [†]. But if this syrup be gain diluted with water, and placed in favourable cir- umstances, it will ferment. Therefore the presence of *ater* is absolutely necessary for the existence of vinous ermentation. But, on the other hand, if the must be oo much diluted with water, it either refuses to fer- nent altogether, or its fermentation proceeds very lan- uidly.

Sugar,

If the juice of those fruits which contain but little ugar, as currants, be put into a favourable situation, ermentation indeed takes place, but so slowly, that the roduct is not *wine*, but *vinegar*: but if a sufficient quantity of sugar be added to these very juices, wine is eadily produced. No substance whatever can be made o undergo vinous fermentation, and to produce wine, nless sugar be present. *Sugar* therefore is absolutely necessary for the existence of vinous fermentation; and we are certain that it is decomposed during the process; for no sugar can be obtained from properly fermented wine. It has been sufficiently demonstrated by the experiments of Macquer and the observations of Chaptal, that the strength of the wine is always proportional to the quantity of sugar contained in the must [‡].

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[*] Fabroni, *Ann. de Chim.* xxxi. 302.

[†] Stahl, i.

[‡] *Ann. de Chim.* xxxvi. 37.

An acid,

All those juices of fruits which undergo the vinous fermentation, either with or without the addition of sugar, contain an acid. We have seen already in the First Chapter that the vegetable acids are obtained chiefly from fruits. The apple, for instance, contains malic acid; the lemon, citric acid; the grape, tartarous and malic acids. The Marquis de Bullion has ascertained that *must* will not ferment if all the tartarous acid which it contains be separated from it; but it ferments perfectly well on restoring that acid. The same chemist ascertained that the strength of wine is considerably increased by adding tartar and sugar to the must *. We may conclude from these facts, that the presence of a vegetable acid is absolutely necessary for the commencement of the vinous fermentation. This renders it probable that the essential part of barm is a vegetable acid, or something equivalent; for if sugar be dissolved in four times its weight of water, mixed with the yeast of beer, and placed in a proper temperature, it undergoes the vinous fermentation †.

And extract, are necessary.

All the juices of fruits which undergo the vinous fermentation contain an *extractive matter*, composed of what Deyeux has called the *sweet principle*. This substance has not been examined with much precision; but it seems to consist of mucilage, jelly, and extract. Now the presence of this substance is also necessary for the commencement of fermentation. For sugar, though diluted with water, and mixed with a vegetable acid, refuses to ferment unless some mucilaginous matter be added.

Thus we see, that for the production of wine a cer-

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* *Ann. de Chim.* xxxvi. 20.

† Bergman.

in temperature, a certain portion of water, sugar, a
getable acid, and extractive matter, is necessary. Mr
avoisier found that sugar would not ferment unless
ssolved in at least four times its weight of water.
is seems to indicate that the particles of sugar must
removed to a certain distance from each other before
e other ingredients can decompose them.

Phenomena of the fermentation.

When all these substances exist in must in proper
oportions, the fermentation commences very speedily,
ovided the liquid be placed in a proper temperature;
d its rapidity (other things remaining the same) is
ways proportioned to the quantity of liquid exposed
once to fermentation. The heat evolved is always
oportioned to the rapidity of the process, and indeed
ay be looked upon as the great cause of that rapidity.
ccording to Chaptal, the temperature during fermen-
tion is never lower than 60°, and sometimes it is as
igh as 95 [*].

During the fermentation, the quantity of sugar is
onstantly diminishing, and when the process is com-
leted the whole of the sugar is decomposed. The li-
uid has become more fluid, and has acquired a vinous
ste, owing most probably to the formation of alcohol.
Whether the other substances, which constitute a part
f the must, have undergone any change, or whether
ey have merely contributed to the decomposition of
e sugar, is not precisely known. The experiments
f Lavoisier, to whom we are indebted for the first
recise explanation of fermentation, render the second
upposition most probable. From these experiments it
ollows, that the sugar is divided into two portions; one

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[*] *Ann. de Chim.* xxxvi. 25.

portion separates in the form of carbonic acid, and the other, containing a great excess of hydrogen, remain under the form of alcohol. This alcohol is combined with the colouring matter, and with the acids of the wine, so intimately, that it can only be separated by distillation. The carbonic acid carries along with it a certain portion of alcohol, as was pointed out some time ago by Chaptal. The extractive matter separates, either precipitating to the bottom or swimming on the surface.

It seems more than probable, from the experiments of Bullion and Chaptal, that the tartarous acid is partly decomposed during the fermentation, and that a portion of malic acid is formed. The process, therefore, is more complicated than was suspected by Lavoisier. It is obviously analogous to combustion, as is evident from the evolution of caloric and the formation of carbonic acid, which is a product of combustion. Perhaps the tartarous acid and the extractive matter, by attracting at once the oxygen of the sugar, destroy the equilibrium, and occasion a commencement of decomposition, which is afterwards completed at the expence of the sugar.

After the fermentation has ceased, the liquor is put into casks, where the remainder of the sugar is decomposed by a slow fermentation; after which the wine, decanted off the extractive matter, is put up in bottles.

Component parts of wine.

The properties of wine differ very much from each other according to the nature of the grapes from which the *must* was extracted, and according to the manner in which the process was conducted. These differences are too well known to require a particular description. But all wines contain less or more of the following ingredients ; not to mention water, which constitutes a ery great proportion of every wine.

An acid,

1. An acid. All wines give a red colour to paper tained with turnsole, and of course contain an acid. Chaptal has ascertained that the acid found in greatest bundance in wine is the malic ; but he found traces lso of citric acid, and it is probable that wine is ne-er entirely destitute of tartar. All wines which have he property of frothing when poured into a glass, con-ain also carbonic acid, to which they owe their brisk-ess. This is the case with champaign. These wines re usually weak ; their fermentation proceeds slowly, nd they are put up in close vessels before it be over. Hence they retain the last portions of carbonic acid that have been evolved.

Alcohol,

2. Alcohol. All wine contains less or more of this principle, to which it is indebted for its strength ; but in what particular state of combination it exists in wine cannot easily be ascertained. It is undoubtedly intimately combined with the other component parts of wine ; as Fabroni has shewn that it cannot be separa-ted by saturating the wine with dry carbonat of pot-ass, though a very small portion of alcohol, added on purpose to wine, may be easily separated by means of that salt. But as alcohol separates along with the carbonic acid during the fermentation we can scarcely doubt that it has been formed. When wine is distilled, the alcohol readily separates. The distillation is usually continued as long as the liquid which comes over is inflammable. The quantity obtained varies according to the wine, from a fourth part to a fourteenth part of the wine distilled. The spirit thus obtained is well known under the name of *brandy*. What remains

after this distillation is distinguished in France by the name of *vinasse*. It consists of tartar, &c. and when evaporated to dryness, and subjected to combustion, yields potass.

Extract,

3. Extractive matter. This matter exists in all wines; but its proportion diminishes according to the age of the wine, as it gradually precipitates to the bottom.

Oil,

4. Every wine is distinguished by a peculiar flavour and odour, which probably depends upon the presence of a volatile oil, so small in quantity that it cannot be separated.

And colouring matter.

5. The *colouring matter* of wine is originally contained in the husk of the grape, and is not dissolved till the alcohol be developed. This matter is analogous to the other colouring matters of plants: a set of bodies possessed of remarkable properties, but too little examined hitherto to be introduced with much advantage into a System of Chemistry. This colouring matter precipitates when the wine is exposed to the heat of the sun. It sometimes also precipitates in old wine, and it may be easily separated by pouring lime-water into wine*.

SECT. III.

OF BEER.

THE method of making beer was known in the most remote ages; we are ignorant to whom the world is in-

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* The most precise account of wine and of the vinous fermentation hitherto published, is by Chaptal, and is contained in the xxxvi. and xxxvii. volumes of the *Annales de Chimie*.

debted for the discovery of it. Beer is usually made from *barley*.

Method of making malt,

The barley is steeped in water for about sixty hours, in order to saturate it with that liquid. It ought then to be removed as speedily as possible, otherwise the water dissolves and carries off the most valuable part of the grain. The barley is then to be laid in a heap for twenty-four hours; heat is evolved, oxygen gas absorbed, carbonic acid gas emitted, and germination commences with the shooting forth of the radicle. It is then spread upon a cool floor, dried slowly, and is afterwards known by the name of *malt*[*].

Wort,

Malt, previously ground to a coarse powder, is to be infused in a sufficient quantity of pure water, of the temperature of 160°, for an hour. The infusion is then to be drawn off, and more water may be added, at a higher temperature, till all the soluble part of the malt is extracted. This infusion is known by the name of *wort*. It has a sweet taste, and contains a quantity of saccharine, and doubtless also of gelatinous matter.

And beer.

When *wort* is placed in the temperature of about 60°, fermentation gradually takes place in it, and the very same phenomena appear which distinguish the production of wine. The fermentation of wort, then, is nothing but a particular case of the vinous fermentation. But wort does not ferment so well, nor so soon, nor does it produce nearly so great a quantity of good fermented liquor, as when *yeast* is added to it. The reason of which is, probably, that the fermentation does not commence till an acid is generated in the wort, and before that happens part of the saccharine contents are

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[*] Collier, *Manch. Mem.* v. 266.

decomposed ; whereas the yeast adds an acid, or at least something equivalent to it, at once.

Wort ferments in close vessels, as Mr Collier ascertained by experiment, equally well as in the open air. Therefore the decomposition is produced entirely by the substances contained in the wort, without the addition of any thing from the air. The quantity of beer produced in close vessels is much greater than when the process takes place in the open air. The reason of which is, that in the open air the beer gradually evaporates during the fermentation. Thus Mr Collier found that 11 quarts, 3½ oz. fermented in open vessels, lost in 12 days, 40 oz. ; whereas an equal weight, fermented in close vessels, lost only 8 oz. in the same time. Yet the quality of the *beer* was the same in each ; for equal quantities of both, when distilled, yielded precisely the same portion of alcohol[*].

During the fermentation, a quantity of carbonic acid gas is constantly disengaged, not in a state of purity, but containing, combined with it, a portion of the wort; and if this gas be made to pass through water, it will deposite wort, which may be fermented in the usual manner[†].

When beer is distilled, alcohol is obtained, and the residuum is an acid liquor[‡]. The theory of beer is so obviously the same with that of wine that it requires no additional explanation.

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[*] Collier, *Manch. Mem.* v. 260.

[†] Ibid.

[‡] Henry, *Manch. Mem.* ii. 257.

SECT. IV.

OF THE ACETOUS FERMENTATION.

Wine ferments and becomes sour.

If wine or beer be kept in a temperature between 70° and 90°, it gradually becomes thick, its temperature augments, filaments are seen moving through it in every direction, and a kind of hissing noise may be distinguished. These intestine motions gradually disappear, the filaments attach themselves to the sides and bottom of the vessel, and the liquor becomes transparent. But it has now lost its former properties, and is converted into acetous acid. This intestine decomposition has been long distinguished by the name of *acetous fermentation*, because its product is *acetous acid*. That this fermentation may take place, certain conditions must be attended to. The most important of these will appear from the following observations:

Alcohol not susceptible of this change.

1. Neither pure alcohol, nor alcohol diluted with water, is susceptible of this change. The weaker the wine or the beer is on which the experiment is made, the more readily is it converted into vinegar; the stronger they are they resist the change with the greater obstinacy. But it results from the experiments of Beccher, that strong wines, when they are made to undergo the acetous fermentation, yield a much better and stronger vinegar than weak wines. Hence it follows, that alcohol, though of itself it refuses to undergo the change, yet when other bodies are present which readily fer-

ment, is decomposed during the process, and contributes to the formation of the acetous acid.

Extractive matter necessary.

2. Wine entirely deprived of extractive matter, either by spontaneous deposition or by clarification, does not undergo the acetous fermentation, unless some mucilaginous matter be mixed with it. Chaptal exposed old wine destitute of this matter, in open bottles, to the greatest summer heat of Montpelier for 40 days, and yet it did not become sour: But upon adding some vine leaves to the same wine, it became acid in a few days *.

Oxygen absorbed.

3. Wine never becomes sour, provided it be completely deprived of all access to atmospheric air. The reason is, that during the acetous fermentation, oxygen is absorbed from the atmosphere in abundance; and unless that absorption can take place, no vinegar is ever formed. Hence the reason that wine or beer is more apt to become sour after the cork has been drawn, and still more apt when part has been poured out of the bottle.

A certain temperature required.

4. A pretty high temperature is necessary for the commencement of the acetous fermentation. Wine or beer (unless very weak) scarcely become sour under the temperature of 65° or 70°. The fermentation is very apt to commence when the temperature suddenly rises. It is said, too, that wine and beer are more apt to become sour at certain seasons of the year than at others.

Effects of the fermentation.

5. When the acetous acid is completed, the whole of the malic acid originally contained in the wine has disappeared as well as the alcohol. We must conclude, therefore, that they have been both converted into ace-

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* *Ann. de Chim.* xxxvi. 245.

tous acid. Part of the extractive matter has also undergone the same change, and seems indeed to have been the substance that first began the absorption of oxygen. Part of it is deposited in the state of flakes; part remains in solution, and disposes the vinegar to decomposition. Vinegar also contains a little tartar, and probably also citric acid. Malic acid is also found in new vinegar; a proof that this part of the wine is the last to undergo the acetous fermentation.

Acetous acid formed by other processes.

6. Acetous acid is formed in many other cases of the decomposition of vegetables besides the acetous fermentation. These have been pointed out with much ingenuity by Vauquelin and Fourcroy. They may be reduced under three heads. *First*, When sugar, gum, tartar, wood, &c. are distilled in a retort, or even burnt in the open fire, acetous acid separates in combination with an empyreumatic oil which distinguishes its odour. Hence it was mistaken for other acids, and distinguished by the names of *pyromucous*, *pyrolignous*, *pyrotartarous acids*, till its real nature was ascertained by these distinguished chemists *. *Secondly*, When concentrated sulphuric acid is poured upon the same vegetable bodies, they are decomposed in a very different manner; being converted into water, charcoal, and acetous acid. *Thirdly*, Acetous acid is evolved in considerable quantity during the spontaneous decomposition of urine and some other animal substances. Thus it appears, that the component parts of acetous acid are extremely apt to combine together in these proportions which constitute that important acid.

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* *Ann. de Chim.* xxxv. 183.

SECT. V.

OF PUTREFACTION.

Nature of putrefaction.

ALL vegetable substances, both complete plants and their component parts separately, when left entirely to themselves, are gradually decomposed and destroyed, provided moisture be present, and the temperature be not much under 45°, nor too high to evaporate suddenly all the moisture. This decomposition has obtained the name of *putrefaction*.

It proceeds with most rapidity in the open air; but the contact of air is not absolutely necessary. Water is in all cases essential to the process, and therefore is most probably decomposed.

Putrefaction is constantly attended with a fetid odour, owing to the emission of certain gaseous matters, which differ according to the putrefying substance. Some vegetable substances, as gluten and cruciform plants, emit ammonia; others, as onions, seem to emit phosphorated hydrogen gas. Carbonic acid gas, and hydrogen gas, impregnated with unknown vegetable matters, are almost constantly emitted in abundance. When the whole process is finished, scarcely any thing remains but the salts, the metals, and the earths, which formed a constituent part of the vegetable, often combined with acetous and carbonic acids. But our chemical knowledge of vegetable compounds is still by far too limited to enable us to follow this very complicated process with any chance of success.

BOOK V.

OF

ANIMALS.

Animals and vegetables

When we compare animals and vegetables together, each in their most perfect state, nothing can be easier than to distinguish them. The plant is confined to a particular spot, and exhibits no marks of consciousness or intelligence; the animal, on the contrary, can remove at pleasure from one place to another, is possessed of consciousness, and a high degree of intelligence. But on approaching the contiguous extremities of the animal and vegetable kingdom, these striking differences gradually disappear, the objects acquire a greater degree of resemblance, and at last approach each other so nearly, that it is scarcely possible to decide whether some of those species which are situated on the very boundary belong to the animal or vegetable kingdom.

Not easily distinguished.

To draw a line of distinction, then, between animals and vegetables, would be a very difficult task: but it is not necessary at present to attempt it; for almost the only animals whose bodies have been hitherto examined with any degree of chemical accuracy, belong to the most perfect classes, and consequently are in no danger of being confounded with plants. Indeed the greater number of facts which I have to relate, apply only to the human body, and to those of a few domestic animals. The task of analysing all animal bodies is immense, and must be the work of ages of indefatigable industry.

This part of the subject naturally divides itself into four Chapters. In the First Chapter I shall give an account of the different ingredients hitherto found in animals, such of them at least as have been examined with any degree of accuracy: in the Second, I shall treat of the different members of which animal bodies are composed; which must consist each of various combinations of the ingredients described in the First Chapter: in the Third, I shall treat of those animal functions which may be elucidated by chemistry: and, in the Fourth, of the changes which animal bodies undergo after death.

CHAP. I.

OF ANIMAL SUBSTANCES.

THE substances which have been hitherto detected in the animal kingdom, and of which the different parts of animals, as far as these parts have been analysed, are found to be composed, may be arranged under the following heads:

1. Fibrina.
2. Albumen.
3. Gelatine.
4. Mucilage.
5. Urea.
6. Sugar.
7. Oils.
8. Resins.
9. Sulphur.
10. Phosphorus.
11. Acids.
12. Alkalies.
13. Earths.
14. Metals.

These shall form the subject of the following Sections.

SECT. I.

OF FIBRINA.

How obtained.

If a quantity of blood, newly drawn from an animal, be allowed to remain at rest for some time, a thick red clot gradually forms in it, and subsides. Separate this clot from the rest of the blood, put it into a linen cloth, and wash it repeatedly in water till it ceases to give out any colour or taste to the liquid—the substance which remains after this process is denominated *fibrina*. It has been long known to physicians under the name of the *fibrous part of the blood*, but has not till lately been accurately described.

Properties.

Fibrina is of a white colour, has no taste, and is insoluble in water and in alcohol. It is soft and ductile, has a considerable degree of elasticity, and resembles very much the gluten of vegetables. When boiled long in water it contracts considerably, becomes harder, loses its elasticity, and becomes somewhat brittle.

Action of alkalies,

The alkalies diluted with water have but little action on it, and the earths none at all; but the fixed alkalies, when very much concentrated, give it a deep brown colour by the assistance of heat, occasion the disengagement of ammonia, and dissolve it entirely, forming with it a viscid bitter tasted soap, decomposable by acids. It is probable that the alkaline earths have the same effects on it *.

And acids.

Acids dissolve it, even when pretty much diluted. Sulphuric acid gives it a deep brown colour, charcoal is precipitated, and water and acetous acid are formed. Diluted nitric acid occasions the disengagement of a good deal of azotic gas; afterwards, if the heat be increased, prussic acid comes over, and carbonic acid gas mixed with nitrous gas; the fibrina is totally decomposed, oxalic acid is formed, and yellow waxy flakes make their appearance in the liquid. Muriatic acid dissolves it, and forms with it a green-coloured jelly. The acetous, citric, oxalic, and tartarous acids also dissolve it by the assistance of heat; and the solutions, when concentrated, assume the appearance of a jelly. Alkalies precipitate the fibrina from acids in flakes, soluble in hot water, and resembling *gelatine* in its properties †.

Its decomposition.

Fibrina soon putrefies when allowed to remain in water, a fetid and ammoniacal odour is perceived, and the fibrina is converted into a species of tallow. When distilled it yields water, carbonat of ammonia, a thick, heavy, fetid oil, zoonic acid, and carbonic acid, and carbonated hydrogen gas. The charcoal is brilliant, and difficult to incinerate; it leaves, when burnt, a little phosphat of lime ‡.

Composition.

These facts are sufficient to shew us that this substance is composed of azot, hydrogen, and carbon;

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* Fourcroy, ix. 158.   † Ibid.   ‡ Ibid. 157.

but neither the precise proportion of these ingredients, nor the manner of their combination, are at present known. As it yields more azotic gas and ammonia than any other animal substance, we must conclude that it contains a greater proportion of azot than any other substance known, unless urea be excepted.

SECT. II.

OF ALBUMEN.

Contained in eggs.

The eggs of fowls contain two very different substances: a yellow oily-like matter, called the *yolk;* and a colourless glossy viscid liquid, distinguished by the name of *white.* This last is the substance which chemists have agreed to denominate *albumen*[*]. The white of an egg, however, is not pure albumen. It contains, combined with it, some soda and some sulphur; but as albumen is never found except combined with these bodies, and as no method is known of separating it without at the same time altering the properties of the albumen, chemists are obliged to examine it while in combination with these bodies.

Coagulates when heated.

Albumen dissolves readily in water, and the solution has the property of giving a green colour to vegetatable blues, in consequence of the soda which it contains. When albumen is heated to the temperature of 165°[†],

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[*] This is merely the Latin term for the white of an egg. It was first introduced into chemistry by the physiologists.

[†] Cullen.

it *coagulates* into a white solid mass; the consistency of which, when other things are equal, depends, in some measure, on the time during which the heat was applied. The coagulated mass has precisely the same weight that it had while fluid. This property of coagulating when heated, is characteristic of albumen, and distinguishes it from all other bodies.

Phenomena of the coagulation.

The taste of coagulated albumen is quite different from that of liquid albumen: its appearance, too, and its properties, are entirely changed; for it is no longer soluble, as before, either in hot or in cold water.

The coagulation of albumen takes place even though air be completely excluded; and even when air is present there is no absorption of it, nor does albumen in coagulating change its volume *. Acids have the property of coagulating albumen, as Scheele ascertained †. Alcohol also produces, in some measure, the same effect. *Heat*, then, *acids*, and *alcohol*, are the agents which may be employed to coagulate albumen.

It is remarkable, that if albumen be diluted with a sufficient quantity of water, it can no longer be coagulated by any of these agents. Scheele mixed the white of an egg with ten times its weight of water, and then, though he even *boiled* the liquid, no coagulum appeared. Acids, indeed, and alcohol, even then coagulated it; but they also lose their power if the albumen be diluted with a much greater quantity of water, as has been ascertained by many experiments. Now when water is poured into albumen, its integrant particles must be farther separated from each other, and their distance must increase with the quantity of water with which

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* Carradori, *Ann. de Chim.* xxix. 98.

† Scheele, ii. 58.

they are diluted. We see, therefore, that albumen ceases to coagulate whenever its particles are separated from each other beyond a certain distance. That no other change is produced, appears evident from this circumstance, that whenever the watery solution of albumen is sufficiently concentrated by evaporation, coagulation takes place, upon the application of the proper agents, precisely as formerly.

It does not appear that the distance of the particles of albumen is changed by coagulation; for coagulated albumen occupies precisely the same sensible space as liquid albumen *.

Inquiry into its cause.

Now to what is the coagulation of albumen owing? We can conceive no change to take place from a state of liquidity to that of solidity, without some change in the figure of the particles of the body which has undergone that change. Now such a change may take place three ways: 1. The figure may be changed by the addition of some new molecules to each of the molecules of the body. 2. Some molecules may be abstracted from every integrant particle of the body. 3. Or the molecules, of which the integrant particles are composed, may enter into new combinations, and form new integrant particles, whose form is different from that of the old integrant particles. Some one or other of these three things must take place during the coagulation of albumen.

1. Scheele and Fourcroy have ascribed the coagulation of albumen to the first of these causes, namely, to the addition of a new substance. According to Scheele, *caloric* is the substance which is added. Fourcroy, on the contrary, affirms that it is *oxygen*.

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* Carradori.

Ascribed to caloric,

Scheele supported his opinion with that wonderful ingenuity which shone so eminently in every thing which he did. He mixed together one part of white of egg and four parts of water, added a little pure alkali, and then dropt in as much muriatic acid as was sufficient to saturate the alkali. The albumen coagulated: but when he repeated the experiment, and used carbonat of alkali instead of pure alkali, no coagulation ensued. In the first case, says he, there was a double decomposition: the muriatic acid separated from a quantity of caloric with which it was combined, and united with the alkali; while, at the same instant, the caloric of the acid united with the albumen, and caused it to coagulate. The same combination could not take place when the alkaline carbonat was used, because the carbonic acid gas carried off the caloric, for which it has a strong affinity *.

To oxygen.

Fourcroy observes, in support of his opinion, that the white of an egg is not at first capable of forming a hard coagulum, and that it only acquires that property by exposure to the asmosphere. It is well known that the white of a new laid egg is milky after boiling; and that if the shell be covered over with grease to exclude the external air, it continues long in that state; whereas the white of an old egg, which has not been preserved in that manner, forms a very hard tough coagulum. These facts are undoubted; and they render it exceedingly probable, that albumen acquires the property of forming a hard coagulum only by absorbing oxygen: but they by no means prove that coagulation itself is owing to such an absorption. And since coagulation takes place with-

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* Scheele, ii. 58.

out the presence of air, and since no air, even when it is present, is absorbed, this opinion cannot be maintained without inconsistency.

2. The only substance which can be supposed to leave albumen during coagulation, since it does not lose its weight, is *caloric*. We know that in most cases where a fluid is converted into a solid, caloric is actually disengaged. It is extremely probable, then, that the same disengagement takes place here. But the opinion has not been confirmed by any proof. Fourcroy indeed says, that in an experiment made by him, the thermometer rose a great number of degrees. But as no other person has ever been able to observe any such thing, it cannot be doubted that this philosopher has been misled by some circumstance or other to which he did not attend *.

Its real cause.

3. The coagulation of albumen resembles exactly what takes place when concentrated silicated potass is exactly saturated with muriatic acid. The mass slowly assumes an opal colour, and at last concretes into a solid gelatinous mass. Now this jelly consists of the particles of silica combined with each other, and with a certain portion of water. These particles were formerly held in solution by the potass; that is to say, the affinity of silica for potass was superior to the cohesive force which exists between the particles of silica. The muriatic acid, by saturating the potass, diminished the force of its affinity for the silica. The cohesive force of the silica, now superior, causes it to combine in masses, consisting of a certain portion of silica and water. These masses, equally diffused through the liquid, and at such

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* Thomson's *Fourcroy*, iii. 271.

small intervals as to cohere together, gives the whole a gelatinous form. Something like this seems to take place with respect to the albumen. Its particles, combined with water and also with soda, are all kept at equal distances in the liquid; because this affinity just balances their cohesive force. But when heat is applied, this affinity is diminished by the additional elasticity, or tendency to separate, given to the water and the soda. The cohesion of the albumen, now superior, causes its particles to combine in sets, forming solid bodies, equally distant from each other, and cohering together. Hence the gelatinous form, and the solidity of the coagulum, always inversely proportional to the quantity of water present. Thus it appears, that whatever diminishes the affinity between the water and soda and the albumen, occasions its coagulation, by allowing its cohesive force to act.

Action of tan on albumen.

If the solution of tan be poured into an aqueous solution of uncoagulated albumen, it forms with it a very copious yellow precipitate of the consistence of pitch, and insoluble in water. This precipitate is a combination of tan and albumen. When dry it is brittle, like over-tanned leather, and is not susceptible of putrefaction. This property which albumen has of precipitating with tan was discovered by Seguin *: it furnishes us with a method of detecting the presence of albumen in any liquid in which we suspect it. Several of the metallic salts occasion a precipitate in solutions of albumen. The precipitate is a combination of the albumen with the oxide, which is often brought nearer to the metallic state.

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* Nicholson's *Journal*, i. 271.

Chap. I.

Action of alkalies,

Pure alkalies and alkaline earths dissolve albumen ; at the same time ammonia is disengaged, owing to the decomposition of part of the albumen. Acids precipitate the albumen from alkalies, but its properties are changed *.

And acids.

Coagulated albumen is dissolved by the mineral acids greatly diluted with water ; and if a concentrated acid be added to the solution, the albumen is again precipi-ated †. Alkalies, however, do not precipitate it from ts solution in acids ‡. But if a solution of tan be poured into the acid solution of albumen, a very copious precipitate appears §.

Nitric acid, when assisted by heat, disengages azotic gas from albumen || ; but the quantity is not so great s may be obtained from fibrina ¶. The albumen is gradually dissolved, nitrous gas is emitted, oxalic and malic acids are formed, and a thick oily matter makes ts appearance on the surface **. When distilled it furnishes the same products as fibrina, only the quantity of mmonia is not so great ††.

Its composition.

Hence it follows, that albumen is composed of azot, ydrogen, and carbon, as well as fibrina ; but the pro-ortion of azot is not so great in the first substance as n the second.

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* Scheele, ii. 57. † Ibid. ‡ Vauquelin, *Ann. de Chim.* xxix. 15.

Ibid. || Scheele and Berthollet.

¶ Fourcroy, *Ann. de Chim.* i. 41.

** Scheele, Crell's *Annals*, ii. 17. English Translation.

†† Fourcroy, *Ann. de Chim.* i. 43.

SECT. III.

OF GELATINE.

How obtained.

If a piece of the fresh skin of an animal, an ox, for instance, after the hair and every impurity is carefully separated, be washed repeatedly in cold water till the liquid ceases to be coloured, or to abstract any thing; if the skin, thus purified, be put into a quantity of pure water, and boiled for some time, part of it will be dissolved. Let the decoction be slowly evaporated till it is reduced to a small quantity, and then put aside to cool. When cold, it will be found to have assumed a solid form, and to resemble precisely that tremulous substance well known to every body under the name of *jelly*. This is the substance called in chemistry *gelatine*. If the evaporation be still farther continued, by exposing the jelly to dry air, it becomes hard, semitransparent, breaks with a glassy fracture, and is in short the substance so much employed in different arts under the name of *glue*. Gelatine, then, is precisely the same with glue; only that it must be supposed always free from those impurities with which glue is so often contaminated.

Its properties.

Gelatine is transparent and colourless; when thrown into water, it very soon swells, and assumes a gelatinous form, and gradually dissolves completely. By evaporating the water, it may be obtained again unaltered in the form of jelly. Cold water dissolves it slowly, but water at the temperature of 90° dissolves it rapidly.

Hence the difficulty of obtaining jellies in very warm weather. The property of assuming a gelatinous form is characteristic of gelatine.

Action of alkalies and acids,

Alkalies dissolve gelatine, especially when assisted by heat. The acids dissolve it with great facility, even when diluted. Nitric acid disengages from it a small quantity of azotic gas; dissolves it when assisted by heat, excepting an oily matter, which appears on the surface of the solution; and converts it partly into oxalic and malic acids *.

Of alcohol,

Gelatine is insoluble in alcohol, and is even precipitated from water when very much concentrated: but a weak solution of gelatine in water may be mixed with $\frac{1}{4}$th its weight of alcohol without any precipitation. It is in this state that solutions of gelatine are usually preserved by chemists.

Of tan.

When the solution of tan is dropt into gelatine, a copious yellowish white precipitate appears, which soon forms an elastic adhesive mass, not unlike vegetable gluten. This precipitate is composed of gelatine and tan; it soon dries in the open air, and forms a brittle resinous-like substance, insoluble in water, capable of resisting the greater number of chemical agents, and not susceptible of putrefaction. It resembles exactly overtanned leather.

Of heat.

Heat decomposes gelatine completely like other animal substances. When distilled in a retort, it yields water impregnated with ammonia, a thick fètid oil, zoonat of ammonia, and a porous charcoal, easily burnt, and leaving behind a little phosphat of lime, and some muriat of potass and of soda †.

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* Scheele, Crell's *Annals*, ii. 17. English Trans.

† Fourcroy, ix. 233.

When gelatine is allowed to remain dissolved in water, it first acquires acid properties, and then putrefies. This substance has been compared to gum, which it resembles indeed in many of its properties, but from which it differs in several others. Its uses in the state of glue are various and important; and in the state of jelly, or dissolved in soup, it constitutes one of the most nourishing articles of the food of man.

SECT. IV.

OF ANIMAL MUCILAGE.

No word in chemistry is used with less accuracy than *mucilage*. It serves as a common name for almost every animal substance which cannot be referred to any other class.

None of the substances to which the name of *animal mucilage* has been given have been examined with care; of course it is unknown whether these substances be the same or different.

Whenever an animal substance possesses the following properties, it is at present denominated an animal mucilage by chemists.

Characters.

1. Soluble in water.
2. Insoluble in alcohol.
3. Neither coagulable by heat, nor concreting into a jelly by evaporation.
4. Not precipitated by the solution of tan.

Most of the substances called *mucilage* have also the property of absorbing oxygen, and of becoming by that means insoluble in water. They resemble vegetable extract in this respect.

The mucilaginous substances shall be pointed out in the next Chapter. In the present state of our knowledge, any account of them here would merely be a repetition of the properties just mentioned.

SECT. V.

OF UREA.

How obtained.

Urea may be obtained by the following process: Evaporate by a gentle heat a quantity of human urine voided six or eight hours after a meal, till it be reduced to the consistence of a thick syrup. In this state, when put by to cool, it concretes into a crystalline mass. Pour, at different times, upon this mass four times its weight of alcohol, and apply a gentle heat; a great part of the mass will be dissolved, and there will remain only a number of saline substances. Pour the alcohol solution into a retort, and distil by the heat of a sand-bath till the liquid, after boiling some time, is reduced to the consistence of a thick syrup. The whole of the alcohol is now separated, and what remains in the retort crystallizes as it cools. These crystals consist of the substance known by the name of *urea*[*].

Discovery.

It was first described by Rouelle the Younger in 1773, under the name of the *saponaceous extract of urine*. He mentioned several of its properties; but

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[*] Fourcroy and Vauquelin, *Ann. de Chim.* xxxii. 86.

very little was known concerning its nature till Fourcroy and Vauquelin published their experiments on it in 1799. These celebrated chemists have given it the name of *urea*, which has been generally adopted.

Properties.

Urea, obtained in this manner, has the form of crystalline plates crossing each other in different directions. Its colour is yellowish-white: it has a fetid smell, somewhat resembling that of garlic or arsenic; its taste is strong and acrid, resembling that of ammoniacal salts; it is very viscid and difficult to cut, and has a good deal of resemblance to thick honey*. When exposed to the open air, it very soon attracts moisture, and is converted into a thick brown liquid. It is extremely soluble in water; and during its solution a considerable degree of cold is produced†. Alcohol dissolves it with facility, but scarcely in so large a proportion as water. The alcohol solution yields crystals much more readily on evaporation than the solution in water.

Crystallizes with nitric acid.

When nitric acid is dropt into a concentrated solution of urea in water, a great number of bright pearl-coloured crystals are deposited, composed of urea and nitric acid. No other acid produces this singular effect. The concentrated solution of urea in water is brown, but it becomes yellow when diluted with a large quantity of water. The infusion of nutgalls gives it a yellowish brown colour, but causes no precipitate. Neither does the infusion of tan produce any precipitate‡.

Action of heat.

When heat is applied to urea, it very soon melts, swells up and evaporates with an insupportably fetid odour. When distilled, there comes over first benzoic

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* Fourcroy and Vauquelin, *Ann. de Chim.* xxxii. 87.

† Ibid. p. 88.

‡ Ibid.

acid, then carbonat of ammonia in crystals, some carbonated hydrogen gas, with traces of prussic acid and oil; and there remains behind a large residuum, composed of charcoal, muriat of ammonia, and muriat of soda. The distillation is accompanied with an almost insupportably fetid alliaceous odour. Two hundred and eighty-eight parts of urea yield by distillation 200 parts of carbonat of ammonia, 10 parts of carbonated hydrogen gas, 7 parts of charcoal, and 68 parts of benzoic acid, muriat of soda, and muriat of ammonia. These three last ingredients Fourcroy and Vauquelin consider as foreign substances, separated from the urine by the alcohol at the same time with the urea. Hence it follows, that 100 parts of urea, when distilled, yield

92.027	carbonat of ammonia
4.608	carbonated hydrogen gas
3.225	charcoal
99.860	

Composition.

Now 200 parts of carbonat of ammonia, according to Fourcroy and Vauquelin, are composed of 86 ammonia, 90 carbonic acid gas, and 24 water. Hence it follows, that 100 parts of urea are composed of

39.5	oxygen
32.5	azot
14.7	carbon
13.3	hydrogen
100.0	

But it can scarcely be doubted that the water which was found in the carbonat of ammonia existed ready formed in the urea before the distillation[*].

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[*] *Ann. de Chim.* xxxii. 88.

When the solution of urea in water is kept in a boiling heat, and new water is added as it evaporates, the urea is gradually decomposed, a very great quantity of carbonat of ammonia is disengaged, and at the same time acetous acid is formed, and some charcoal precipitates*.

Putrefaction.

When a solution of urea in water is left to itself for some time, it is gradually decomposed. A froth collects on its surface; air bubbles are emitted which have a strong disagreeable smell, in which ammonia and acetous acid are distinguishable. The liquid contains a quantity of acetous acid. The decomposition is much more rapid if a little gelatine be added to the solution. In that case more ammonia is disengaged, and the proportion of acetous acid is not so great†.

Action of sulphuric acid,

When the solution of urea is mixed with one-fourth of its weight of diluted sulphuric acid, no effervescence takes place; but, on the application of heat, a quantity of oil appears on the surface, which concretes upon cooling; the liquid which comes over into the receiver contains acetous acid, and a quantity of sulphat of ammonia remains in the retort dissolved in the undistilled mass. By repeated distillations, the whole of the urea is converted into acetous acid and ammonia‡.

Nitric acid,

When nitric acid is poured upon crystallized urea, a violent effervescence takes place, the mixture frothes, assumes the form of a dark red liquid, great quantities of nitrous gas, azotic gas, and carbonic acid gas, are disengaged. When the effervescence is over, there remains only a concrete white matter, with some drops of reddish liquid. When heat is applied to this residuum,

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* *Ann. de chim.* xxxii. 96.

† Ibid.

‡ Ibid. p. 104.

it detonates like nitrat of ammonia. Into a solution of urea, formed by its attracting moisture from the atmosphere, an equal quantity of nitric acid, of the specific gravity 1.460, diluted with twice its weight of water, was added; a gentle effervescence ensued: a very small heat was applied, which supported the effervescence for two days. There was disengaged the first day a great quantity of azotic gas and carbonic acid gas; the second day, carbonic acid gas, and at last nitrous gas. At the same time with the nitrous gas the smell of the oxy-prussic acid of Berthollet was perceptible. At the end of the second day, the matter in the retort, which was become thick, took fire, and burnt with a violent explosion. The residuum contained traces of prussic acid and ammonia. The receiver contained a yellowish acid liquor, on the surface of which some drops of oil swam*.

Muriatic, and oxy-muriatic acid.

Muriatic acid dissolves urea, but does not alter it. Oxy-muriatic acid gas is absorbed very rapidly by a diluted solution of urea; small whitish flakes appear, which soon become brown, and adhere to the sides of the vessel like a concrete oil. After a considerable quantity of oxy-muriatic acid had been absorbed, the solution, left to itself, continued to effervesce exceeding slowly, and to emit carbonic acid and azotic gas. After this effervescence was over, the liquid contained muriat and carbonat of ammonia.

Action of alkalies.

Urea is dissolved very rapidly by a solution of potass or soda, and at the same time a quantity of ammonia is disengaged; the same substance is disengaged when urea is treated with barytes, lime, or even magnesia.

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* *Ann. de Chim.* xxxii. 107.

Hence it is evident, that this appearance must be ascribed to the muriat of ammonia, with which it is constantly mixed. When pure solid potass is triturated with urea, heat is produced, a great quantity of ammonia is disengaged. The mixture becomes brown, and a substance is deposited, having the appearance of an empyreumatic oil. One part of urea and two of potass, dissolved in four times its weight of water, when distilled give out a great quantity of ammoniacal water; the residuum contains acetite and carbonat of potass*.

When muriat of soda is dissolved in a solution of urea in water, it is obtained by evaporation, not in cubic crystals, its usual form, but in regular octahedrons. Muriat of ammonia, on the contrary, which crystallizes naturally in octahedrons, is converted into cubes, by dissolving and crystallizing it in the solution of urea.

Such are the properties of this singular substance, as far as they have been ascertained by the experiments of Fourcroy and Vauquelin. It differs from all animal substances hitherto examined, in the great proportion of azot which enters into its composition, and in the facility with which it is decomposed, even by the heat of boiling water.

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* *Ann. de Chim.* xxxii. 107.

SECT. VI.

OF SUGAR.

SUGAR has never been found in animals in every respect similar to the sugar of vegetables; but there are certain animal substances which have so many properties in common with sugar, that they can scarcely be arranged under any other name. These substances are,

1. Sugar of milk,
2. Honey,
3. Sugar of diabetic urine.

Sugar of milk.

1. Sugar of milk may be obtained by the following process: Let fresh whey be evaporated to the consistence of honey, and then allowed to cool. It concretes into a solid mass. Dissolve this mass in water, clarify it with the white of eggs, filtre and evaporate to the consistence of a syrup: it deposites on cooling a number of brilliant white cubic crystals, which are *sugar of milk*. Fabricius Bartholet, an Italian, was the first European who mentioned this sugar. He described it in his *Encyclopædia Hermetico dogmatica*, published at Boulognia in 1619; but it seems to have been known in India long before that period. For the best account of its properties we are indebted to Mr Lichtenstein.

Its properties.

When pure it has a white colour, a sweetish taste, and no smell. Its crystals are semitransparent regular parallelopipeds, terminated by four-sided pyramids. Its specific gravity, at the temperature of 55°, is 1.543. At that temperature it is soluble in seven times its weight of water ; but is perfectly insoluble in alcohol. When burnt, it emits the odour of caromel, and exhibits precisely the appearance of burning sugar. When distilled, it yields the same products as sugar, only the empyreumatic oil obtained has the odour of benzoic acid *. When treated with nitric acid it yields *mucous* acid.

Honey

2. Honey is prepared by bees, and perhaps rather belongs to the vegetable than the animal kingdom. It has a white or yellowish colour, a soft and grained consistence, a saccharine and aromatic smell. By distillation it affords an acid phlegm and an oil, and its coal is light and spongy like that of the mucilages of plants. Nitric acid extracts from it oxalic acid precisely as it does from sugar: It is very soluble in water, with which it forms a syrup, and like sugar passes to the vinous fermentation. Mr Cavezzali has proved lately that honey is composed of sugar, mucilage, and an acid. The sugar may be separated by melting the honey, adding carbonat of lime in powder as long as any effervescence appears, and scumming the solution while hot. The liquid thus treated gradually deposites crystals of sugar when allowed to remain in a glass vessel †.

Composed of sugar and an acid.

3. The urine of persons labouring under the disease known to physicians by the name of *diabetes*, yields, when evaporated, a considerable quantity of matter which possesses the properties of sugar.

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* Scheele, ii. [illegible]

† *Ann. de Chim.* xxxix. [illegible]

SECT. VII.

OF OILS.

THE oily substances found in animals may be arraned under three heads: 1. Liquid oils; 2. Fat; 3. Speraceti.

1. The liquid oils are obtained chiefly from different inds of fish, as the whale, &c. They possess the proerties of fixed oils, are more or less contaminated with ucilage, and have a fetid odour.

Fat and tallow.

2. Fat is a well known substance found in all anials. Its consistency varies considerably; but when old it is always more or less solid. When exposed ng to the air, several species of it acquire consisteny, and then it is known by the name of *tallow;* a subance which is also found ready formed in animals, and uch employed in the manufacture of soap and of canles.

Its properties.

It has a white colour, often with a shade of yellow. Vhen fresh it has no smell, and but little taste. While old, it is hard and brittle; but when exposed to the eat of 92°, it melts, and assumes the appearance of oil. he fat, however, which is extracted from flesh by boilng, does not melt till it reaches the temperature of 127°*. allow or fat has, in other respects, the properties of xed oils. When strongly heated with contact of air, emits a smoke of a penetrating smell, which excites

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* Nicholson's *Journal*, i. 71.

tears and coughing, and takes fire when sufficiently heated to be volatilized: the charcoal it affords is not abundant. If fat be distilled on a water-bath, an insipid water, of a slight animal smell, is obtained, which is neither acid nor alkaline, but which soon acquires a putrid smell, and deposites filaments of a mucilaginous nature. This phenomenon, which takes place with the water obtained by distillation on the water-bath from any animal substance, proves that this fluid carries up with it a mucilaginous principle, which is the cause of its alteration. Fat, distilled in a retort, affords phlegm, at first aqueous, and afterwards strongly acid; an oil, partly liquid, and partly concrete; and a very small quantity of charcoal, exceedingly difficult to incinerate, in which Crell found a small quantity of phosphat of lime. These products have an acid and penetrating smell, as strong as that of sulphurous acid. The acid is the sebacic, and is probably formed during the process.

Oxide of fat.

When a little nitric acid is poured upon fat, and a moderate heat applied, the acid deposites its oxygen, and converts the fat into a yellow-coloured ointment, which Fourcroy considers as an oxide of fat, and which is said to have been employed with great success in France in external venereal affections.

Properties of spermaceti.

3. Spermaceti is an oily, concrete, crystalline, semi-transparent matter, of a peculiar smell, which is taken out of the cavity of the cranium of the cachalot; it is purefied by liquefaction, and the separation of another fluid and inconcrescible oil, with which it is mixed. This substance exhibits very singular chemical properties; for it resembles fixed oils in some respects, and volatile oils in others.

When heated to the temperature of 133°[*], it melts; nd if the heat be increased, it evaporates without much lteration. When repeatedly distilled, however, it loses ts solid form, and becomes like oil. When heated in ontact with air, it takes fire, and burns uniformly withut any disagreeable odour: hence its use in making andles.

By long exposure in hot air it becomes yellow and ancid. Pure alkali combines with it, and forms a soap. Nitric and muriatic acids do not affect it, but sulphuric cid dissolves it and alters its colour.

SECT. VIII.

OF ANIMAL RESINS.

Method of obtaining the resin of bile.

SUBSTANCES resembling resins are found in different animal bodies, and which for that reason may be called *animal resins*. The most important of them is the substance which constitutes the basis of the bile. It may be obtained by the following process: Into 32 parts of fresh ox bile pour one part of concentrated muriatic acid. After the mixture has stood for some hours, pass it through a filter, in order to separate a white coagulated substance. Pour the filtrated liquor, which has a fine green colour, into a glass vessel, and evaporate it by a moderate heat. When it has arrived at a certain degree of concentration, a green-coloured substance precipitates. Decant off the clear liquid, and wash the

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[*] Nicholson's *Journal*, i. 71.

precipitate in a small quantity of pure water. This precipitate is the *basis of bile*, or the *resin of bile* as it is sometimes called *.

Its properties.

The resin of bile is of a dark green colour; but when spread out upon paper or on wood, it is a fine grass green: its taste is intensely bitter †.

When heated to about 122° it melts; and if the heat be still farther increased it takes fire and burns with rapidity. It is soluble in water, both cold and hot, and still more soluble in alcohol; but water precipitates it from that liquid ‡.

It is soluble also in alkalies, and forms with them a compound which has been compared to a soap. Acids, when sufficiently diluted, precipitate it both from water and alkalies without any change; but if they be concentrated, the precipitate is redissolved §.

From these properties, it is clear that the resin of bile has a considerable resemblance to vegetable resins; but it differs from them entirely in several of its properties. The addition of oxygen, with which it combines readily, alters it somewhat, and brings it nearer to the class of oils.

Action of oxy-muriatic acid.

In this altered state the resin of bile may be obtained by the following process: Pour oxy-muriatic acid cautiously into bile till that liquid loses its green colour; then pass it through a filter to separate some albumen which coagulates. Pour more oxy-muriatic acid into the filtered liquid, and allow the mixture to repose for some time. The oxy-muriatic acid is gradually converted into common muriatic acid; and in the mean

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* Cadet, *Mem. Par.* 1767, p. 340.

† Ibid. p. 341.

‡ Fourcroy, *Ann. de Chim.* vii. 178.

§ Cadet and Maclurg.

ime the basis of bile absorbs oxygen, and acquires new roperties. Pour into the liquid, after it has remained sufficient time, a little common muriatic acid, a white recipitate immediately appears, which may be separaed from the fluid. This precipitate is the basis of bile ombined with oxygen.

It has the colour and the consistence of tallow, but ill retains its bitter taste. It melts at the temperaure of 104°. It dissolves readily in alcohol, and even water, provided it be assisted by heat. Acids preciitate it from these solutions*.

Resin of urine.

2. The resinous substance discovered by Proust in uman urine does not seem to differ much from the ren of bile. Ear-wax also, from the experiments of auquelin, contains a resin which possesses the same roperties.

Other resins.

3. Castor, civet, and musk, are three other resinous ubstances obtained from different quadrupeds, and well nown for their peculiar odours: but their properties ave not hitherto been investigated by chemists.

SECT. IX.

OF SULPHUR AND PHOSPHORUS.

THESE two simple combustibles constitute a part of any animal substances; but in what state of combinaon they exist in them has not been ascertained. All

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* Fourcroy, *Ann. de Chim.* vii. 176.

that can be done therefore at present is to mention some of the bodies from which they may be separated.

Sulphur.

1. Sulphur seems to be a never-failing attendant on albumen, in whatever part of the body that substance exists as a constituent. Scheele ascertained its presence in the white of an egg and in milk [*]; Parmentier and Deyeux in the blood [†]; Proust in urine and fæces, in the muscles, in hair, &c. and he has made it probable that sulphur is mixed with the matter which is transpired from the body [‡]. This chemist informs us, that in the blood it is combined with ammonia in the state of hydrosulphuret of ammonia; but whether it be in the same state in other parts of the body is not known.

Phosphorus.

2. Phosphorus exhales from different animal bodies during putrefaction in the state of phosphorated hydrogen gas, and of course must have been a constituent part of these bodies. The luminous appearance which some animals exhibit seems, in several instances, to be owing to the presence of this very combustible substance: But the experiments hitherto made upon these animals are not sufficiently decisive.

SECT. X.

OF ACIDS.

The acids which have been discovered ready formed, and constituting a part of animal substances, are the following:

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[*] Scheele, ii. 57.

[†] *Jour. de Phys.* xliv. 457.

[‡] *Ann. de Chim.* xxxvi. 258.

1. Phosphoric.
2. Sulphuric.
3. Muriatic.
4. Carbonic.
5. Benzoic.
6. Uric.
7. Amniotic.
8. Oxalic.
9. Acetous.

sides several others, the nature of which has not hi-rto been ascertained; such as the *formic*, *bombyc*, &c.

Phosphoric,

1. The phosphoric acid is by far the most abundant all the acids found in animals. Combined with lime, constitutes the basis of bone; and the phosphat of e is found in the muscles, and almost all the solid ts of animals; neither are there many of the fluids m which it is absent. In the blood phosphoric acid ound combined with oxide of iron, and in the urine xists in excess, holding phosphat of lime in solution.

Sulphuric,

. Sulphuric acid can scarcely be considered as a nponent part of any of the substances belonging to human body. It is said, indeed, to occur some-es in urine combined with soda. It is, however, a y common constituent of the liquid contents of the rior animals. Thus sulphat of soda is found in the ior of the amnios of cows, and sulphat of lime oc-s usually in the urine of quadrupeds.

Muriatic,

. Muriatic acid occurs in most of the fluid animal stances, and is almost always combined with soda, stituting common salt.

Carbonic,

. Carbonic acid has been detected in fresh human e by Proust, and it occurs in the urine of horses cows abundantly, partly combined with lime.

Benzoic,

. Benzoic acid was first discovered in human urine Scheele, and Fourcroy and Vauquelin have found it ndantly in the urine of cows. Proust has detected the blood, the albumen of an egg, in glue, silk, wool, in the sponge, different species of algæ, and n in mushrooms. This chemist even thinks it probable that it is a constituent of all substances which contain azot *.

Uric.

6. Uric or lithic acid was discovered by Scheele in 1776. It is the most common constituent of urinary calculi, and exists also in human urine. That species of calculus which resembles wood in its colour and appearance, is composed entirely of this substance. It was called at first lithic acid; but this name, in consequence of the remarks made by Dr Pearson on its impropriety, has been laid aside, and that of *uric* acid substituted in its place †.

Its properties.

Uric acid in this state has a brown colour; it is hard and crystallized in small scales. It has neither taste nor smell, is insoluble in cold water, but soluble in 360 parts of boiling water. The solution reddens vegetable blues, especially the tincture of turnsol. A great part of the acid precipitates again as the water cools. It combines readily with alkalies and earths; but the compound is decomposed by every other acid. Muriatic acid has no action on it, neither has sulphuric acid while cold, but when assisted by heat it decomposes it entirely ‡.

Combinations.

When triturated with potass or soda, it forms a saponaceous paste, very soluble in water when there is an excess of alkali, but sparingly when the alkali is neutralized. The urat of potass or of soda is nearly tasteless. The last is found crystallized, constituting gouty concretions §. Ammonia does not dissolve uric acid, but

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* *Ann. de Chim.* xxxvi. 272.

† Dr Pearson rather chuses to call it *uric oxide.*

‡ Scheele, i. 200.

§ Tennant, *Jour. de Phys.* xlv. 399.

Chap. I.

combines with it, and forms a salt not more soluble ıan the pure acid, and resembling it in its external ıaracters. Neither does uric acid dissolve in lime ater; the alkaline carbonats have no action whatever ı it *.

Action of acids.

Nitric acid dissolves it readily; the solution is of a nk colour, and has the property of tinging animal bstances, the skin for instance, of the same colour †. hen this solution is boiled, a quantity of azotic gas, rbonic acid gas, and of prussic acid is disengaged ‡. hen oxy-muriatic acid gas is made to pass into water ntaining this acid suspended in it, the acid assumes a latinous appearance, then dissolves; carbonic acid s is emitted, and the solution yields by evaporation ıriat of ammonia, superoxalat of ammonia, muriatic id, and malic acid §.

Action of heat.

When uric acid is distilled, about a fourth of the acid sses over a little altered, and is found in the receiver ystallized in plates; a few drops of thick oil make eir appearance; $\frac{}{8}$th of the acid of concrete carbonat ammonia, some prussiat of ammonia, some water, d carbonic acid pass over; and there remains in the ort charcoal, amounting to about $\frac{1}{80}$th of the weight the acid distilled ¶.

These facts are sufficient to shew us that uric acid is nposed of carbon, azot, hydrogen, and oxygen; and ıt the proportion of the two last ingredients is much aller than of the other two.

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* Fourcroy, x. 221.

† Scheele and Pearson.

‡ Fourcroy, *Ann. de Chim.* xxvii. 267.

§ Brugnatelli, *Ann. de Chim.* xxvii. 267. Fourcroy, x. 222.

¶ Fourcroy, *Ann. de Chim.* xvi. 116.

Amniotic.

7. Amniotic acid has been lately discovered by Vauquelin and Buniva in the liquor of the amnios of the cow, and may be obtained in white crystals by evaporating that liquid slowly. Hence they have given it the name of amniotic acid. It is of a white and brilliant colour; its taste has a very slight degree of sourness; it reddens the tincture of turnsol; it is scarcely soluble in cold water, but very readily in hot water, from which it separates in long needles as the solution cools. It is soluble also in alcohol, especially when assisted by heat. It combines readily with pure alkalies, and forms a substance which is very soluble in water. The other acids decompose this compound; and the acid of the liquor of the amnios is precipitated in a white crystalline powder. This acid does not decompose the alkaline carbonats at the temperature of the atmospbere, but it does so when assisted by heat. It does not alter solutions of silver, lead, or mercury, in nitric acid. When exposed to a strong heat, it frothes and exhales an odour of ammonia and of prussic acid. The properties are sufficient to shew that it is different from every other acid. It approaches nearest to the mucous and the uric acids; but the mucous acid does not furnish ammonia by distillation like the amniotic. The uric acid is not so soluble in hot water as the amniotic; it does not crystallize in white brilliant needles, and it is insoluble in boiling alcohol; in both which respects it differs completely from amniotic acid *.

Oxalic.

8. Oxalic acid has hitherto been found only in a few urinary calculi by Vauquelin and Foucroy.

Acetous.

9. The acetous acid has been detected in urine by

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* *Ann. de Chim.* xxxiii. 279.

Chap. I.

roust; and Vauquelin and Fourcroy have observed hat acetous acid always makes its appearance during he putrefaction of urine.

Other acids.

Besides these nine acids, Proust has detected another nalogous to the benzoic in urine, an acid called the *ombyc* exists in the silk worm, and a third called *ormic* in the *formica rufa*, or red ant. But as these cids have not been examined minutely, no accurate escription can be given of them. The last, indeed, rom the experiments of Deyeux, is probably the same ith the acetous.

SECT. XI.

ALKALIES, EARTHS, AND METALS.

ALL the alkalies have been found in the fluids of nimals.

Potass.

1. Potass is rather uncommon in the human fluids; ut it has been detected in the milk of cows, and it has een found abundantly in the urine of quadrupeds.

Soda.

2. Soda exists in all the fluids, and seems always to e combined with albumen. Phosphat and muriat of oda are also found. It is this alkali which gives animal uids the property of tinging vegetable blues green.

Ammonia.

3. Ammonia has been detected by Proust in urine; nd it is formed in abundance during the putrefaction f most animal bodies.

II. The only earths hitherto found in animals are ime, magnesia, and silica.

Lime.

1. Lime exists in great abundance in all the larger animals. Combined with phosphoric acid it constitutes the basis of bones, while shells are composed of carbonat of lime. Phosphat of lime is found also in the muscles and other solid parts, and it is held in solution by almost all the fluids.

Magnesia.

2. Magnesia has been detected in human urine by Fourcroy and Vauquelin, combined with phosphoric acid and ammonia. It constitutes also sometimes a component part of the urinary calculi.

Silica.

3. Silica has not hitherto been detected in any of the component parts of animals; but Fourcroy and Vauquelin found it in two human urinary calculi.

III. The metals found in animals are two, namely, iron and manganese.

Iron.

1. Iron combined with phosphoric acid is a constituent part of the blood, and is the substance to which that fluid owes its red colour. Its presence was first ascertained by Manghini, who proved at the same time that it does not exist in the solid parts of animals.

Manganese.

2. Manganese is said to have been detected in animals; but this still requires farther proof.

Such are the substances hitherto found in animals. The simple bodies of which all of them consist are the following:

Substances found in animals.

1. Azot.
2. Carbon.
3. Hydrogen.
4. Oxygen.
5. Phosphorus.
6. Lime.
7. Sulphur.
8. Soda.
9. Potass.
10. Muriatic acid.
11. Magnesia.
12. Silica.
13. Iron.
14. Manganese.

Of these, magnesia and silica may in a great measure e considered as foreign bodies; for they are only found n exceedingly minute quantities, and the last not unless n cases of disease. The principal elementary ingrelients are the first six: animal substances may be conidered as in a great measure composed of them. The irst four constitute almost entirely the soft parts, and he other two form the basis of the hard parts. But ve will be able to judge of this much better after we ave taken a view of the various parts of animals as they xist ready formed in the body. This shall be the subect of the next Chapter.

CHAP. II.

OF THE PARTS OF ANIMALS.

THE different substances which compose the bodies of nimals may be arranged under the following heads:

1. Bones and shells,
2. Muscles,
3. Membranes,
4. Tendons,
5. Ligaments,
6. Glands,
7. Skin,
8. Brain and nerves,
9. Horns and nails,
10. Hair and feathers.

Besides these substances, which constitute the solid part of the bodies of animals, there are a number of luids, the most important of which is the *blood*, which pervades every part of the system in all the larger animals: The rest are known by the name of *secretions*, because they are formed, or *secreted* as the anatomists term it, from the blood. The principal animal secretions are the following:

1. Milk,
2. Saliva,
3. Pancreatic juice,
4. Bile and biliary calculi,
5. Cerumen,
6. Tears,
7. Humours of the eye,
8. Mucus of the nose and other cavities,
9. Sinovia,
10. Semen,
11. Liquor of the amnios,
12. Urine and urinary calculi.

These substances shall form the subject of the following Sections.

SECT. I.

OF BONES AND SHELLS.

Bones, what.

By *Bones* are meant those hard, solid, well known substances, to which the firmness, shape, and strength of animal bodies are owing; which, in the larger animals, form as it were the ground-work upon which all the rest is built. In man, in quadrupeds, and many other animals, the bones are situated below the other parts, and scarcely any of them are exposed to view; but shell-fish and snails have a hard covering on the outside of their bodies, evidently intended for defence. As these coverings, though known by the name of *shells*, are undoubtedly of a bony nature, I shall include them in this Section. For the very same reason, it would be improper to exclude *egg-shells*, and those coverings of certain animals, the tortoise for instance, known by the name of *crusts*.

History.

It had been long known that bones may be rendered soft and cartilaginous by keeping them in diluted acid solutions, and that some acids even dissolve them altogether; that when exposed to a violent heat, they become white, opaque, and brittle; and Dr Lewis had observed, that a sudden and violent heat rendered them hard, semitransparent, and sonorous. But their component parts remained unknown till Scheele mentioned, in his dissertation on Fluor Spar, published in the Stockholm Transactions for 1771, that the earthy part of bones is *phosphat of lime* *. Since that time considerable additions have been made to the chemical analysis of these substances by Berniard, Bouillon, and Rouelle. Mr Hatchett has published some valuable papers on the subject in the Philosophical Transactions for 1799 and 1800; and in the 34th volume of the *Annales de Chimie*, Mr Merat Guillot has given us a table of the component parts of the bones of a considerable number of animals.

The *bony parts* of animals may be divided into three classes; namely, *bones*, *crusts*, and *shells*.

Properties.

1. Bones have a considerable degree of hardness; when recent, they contain a quantity of marrow, which may be partly separated from them. When the water in which bones have been for some time boiled is evaporated to a proper consistence, it assumes the form of a *jelly*; bones therefore contain *gelatine*.

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* The discoverer of this has not been completely ascertained: Scheele does not claim it in that paper; Bergman gives it to Gahn; but Crell affirms that it was made by Scheele.

Contain gelatine,

If a piece of bone be kept for some time in diluted muriatic, or even acetous acid, it gradually loses a considerable part of its weight, becomes soft, and acquires a certain degree of transparency ; and in short acquires the properties of gelatine. Bone therefore consists of gelatine combined with some substance which these acids are capable of dissolving and carrying off.

Phosphat of lime,

If pure ammonia be dropt into the acid which has reduced the bone to this state, a quantity of white powder precipitates, which possesses all the properties of *phosphat of lime*. The substance, then, which was combined with the cartilage is *phosphat of lime*.

Carbonat of lime,

After the phosphat of lime has precipitated, the addition of carbonat of ammonia occasions a farther precipitate, which consists of carbonat of lime : but the quantity of this precipitate is inconsiderable *. When concentrated acids are poured on bones, whether recent or calcined, an effervescence is perceptible ; the gas which escapes renders lime water turbid, and is therefore *carbonic acid*. Now since bones contain carbonic acid, and since they contain lime also uncombined with any acid stronger than carbonic—it is evident that they contain a little *carbonat of lime*. Mr Hatchett found this substance in all the bones of quadrupeds and of fish which he examined †.

And sulphat of lime.

When bones are calcined, and the residuum is dissolved in nitric acid, nitrat of barytes causes a small precipitate, which is insoluble in muriatic acid, and is therefore sulphat of barytes ‡. Consequently bones contain sulphuric acid. It has been ascertained, that this

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* Hatchett, *Phil. Trans.* 1799, p. 327.

† Ibid. ‡ Ibid.

acid is combined with lime. The proportion of *sulphat of lime* in bones is very inconsiderable.

Thus we see that bones are composed of gelatine, of phosphat of lime, carbonat of lime, and sulphat of lime. Proust has shewn that they contain also a considerable quantity of fat. By breaking bones in small pieces, and boiling them for some time in water, he separated this fat which collected on the surface of the water, and weighed when cold one-fourth of the whole weight of the bones employed *. The gelatine can only be separated completely by heating bones strongly with water in a Papin's digester, or by reducing them to powder, and boiling them sufficiently in water. By this last process Proust obtained about $\frac{1}{16}$th of the weight of the bones employed of pure gelatine.

Table of their component parts.

The following TABLE, drawn up by Merat-Guillot †, exhibits a comparative view of the relative proportion of these ingredients in a variety of bones. The sulphat of lime, which occurs only in a very small quantity, has been confounded with phosphat of lime.

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* *Jour. de Phys.* liii. 257.

† *Ann. de Chim.* xxxiv. 71.

One hundred parts contain	Gelatine.	Phosp. of lime.	Carb. of lime.	Loss.
Human bones from a burying-ground,	16	67	1.5	15.5
Do. dry, but not from under the earth,	23	63	2	2
Bone of ox, ...	3	93	2	2
. . . . calf, ...	25	54	trace	21
. . . . horse, ...	9	67.5	1.25	22.25
. . . . sheep, ...	16	70	0.5	13.5
. . . . elk, ...	1.5	90	1	7.5
. . . . hog, ...	17	52	1	30
. . . . hare, ...	9	85	1	5
. . . . pullet, ...	6	72	1.5	20.5
. . . . pike, ...	12	64	1	23
. . . . carp, ...	6	45	0.5	48.5
Horse tooth, ...	12	85.5	0.25	2.25
Ivory, ...	24	64	0.1	11.15
Hartshorn, ...	27	57.5	1	14.5

Enamel.

The enamel of the teeth is composed of the same earthy ingredients as other bones; but it is totally destitute of cartilage *.

Crusts contain most carbonat.

2. The crustaceous coverings of animals, as of echini, crabs, lobsters, prawns, and cray-fish, and also the shells of eggs, are composed of the same ingredients as bones; but in them the proportion of carbonat of lime far exceeds that of phosphat †.

Thus 100 parts of lobster crust contain

60 carbonat of lime
14 phosphat
26 cartilage

100‡

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* Hatchett, *Phil. Trans.* 1799, p. 328. † Ibid. 321. and 324.

‡ Merat-Guillot, *Ann. de Chim.* xxxiv. 71.

One hundred parts of crawfish crust contain

60 carbonat of lime
12 phosphat of lime
28 cartilage

100[*]

One hundred parts of hens egg-shells contain

89.6 carbonat of lime
5.7 phosphat of lime
4.7 animal matter

100.0[†]

Mr Hatchett found traces of phosphat of lime also in ıe shells of snails.

Shells of two kinds:

3. The shells of sea-animals may be divided into two lasses: The first has the appearance of porcelain; their urface is enamelled, and their texture is often slightly brous. Mr Hatchett has given them the name of *porellaneous* shells. The second kind of shell is known y the name of *mother of pearl*. It is covered with a trong epidermis, and below it lies the shelly matter in ıyers[‡]. The shell of the fresh water muscle, mother f pearl, heliotis iris, and turbo olearius, are instances f these shells.

1. Porcelaneous;

Porcelaneous shells are composed of carbonat of ime cemented together by a very small quantity of aninal matter[§].

2. Mother of pearl.

Mother of pearl shells are composed of alternate lay-

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[*] Merat-Guillon, *Ann. de Chim.* xxxiv. 71.

[†] Vauquelin, Ibid. xxix. 6.

[‡] Herissant, *Mem. Par.* 1766, p. 22.—Hatchett, Ibid. 317.

[§] Hatchett, Ibid

Book V.

ers of carbonat of lime and a thin membranaceous substance, which resembles exactly coagulated albumen in its properties. This membrane still retains the figure of the shell after all the carbonat of lime has been separated by acids *.

Mother of pearl contains 66 carbonat of lime,
34 membrane

100 †

Coral.

Coral, which is a bony substance formed by certain sea insects, has a nearer relation to mother of pearl shells in its structure than to any other bony substance, as the following Table ‡ will shew.

	White coral.	Red coral.	Articulated coraline.
Carbonat of lime, . . .	50	53.5	49
Animal matter, ...	50	46.5	51
	100	100.0	100

Other solid animal substances.

From the experiments of Hatchett, it appears that all the solid animal matter of an analogous nature is composed of nearly the same materials. He found the *madrepora virginea*, *muricæ*, and *labyrinthica*, composed of carbonat of lime and a little gelatinous matter; the *madrepora ramea* and *fistularis* of carbonat of lime, and membrane retaining the original figure of the body. The composition of the *millipores* is the same, if we except the *polymorpha*, which yields traces of phosphat of lime. Some idea may be formed of the composition

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* Hatchett, *Phil. Trans.* 1799, p. 318.

† Merat-Guillot, *Ann. de Chim.* xxxiv. 71.

‡ Merat-Guillot, Ibid.

f the other bodies examined by Mr Hatchett from the ollowing TABLE.

BODIES.	COMPOSITION.
ubipora musica	Carbonat of lime, some membrane.
lustra foliacea	Carbonat of lime, membrane, a little phosphat of lime.
orallina opuntia	Carbonat of lime, membrane.
ris ochracea	Carbonat of lime, membrane, a little phosphat, a red powder.
ris hippuris	Carbonat, much membrane.
orgonia nobilis	Carbonat, membrane, some phosphat.
. . . . *ceratophyta*	Carbonat, much membrane, and phosphat.
. . . . *flabellum*	Much membrane and phosphat, some carbonat.
. . . . *suberosa*	Gelatine, carbonat, some phosphat.
. . . . *pectinata*	Membrane, carbonat, some phosphat.
. . . . *setosa*	
. . . . *umbraculum*	Membrane, carbonat.
. . . . *verrucosa*	
. . . . *antiphates*	Membrane, phosphat, little carbonat.
ponges	Membrane like horn soluble in hot water; yield gelatine to hot water.
lcyonium asbestinum	Gelatine, phosphat, carbonat.
. . . . . *ficus*	Membrane, carbonat, some phosphat.
. . . . . . *arboreum*	
ish scales	Membrane, phosphat of lime.

SECT. II.

OF THE MUSCLES OF ANIMALS.

The muscular parts of animals are known in common language by the name of *flesh*. They constitute a considerable proportion of the food of man.

Muscular flesh is composed of a great number of fibres or threads, commonly of a reddish or whitish colour; but its appearance is too well known to require any description. Hitherto it has not been subjected to any accurate chemical analysis. Mr Thouvenel, indeed, has published a very valuable dissertation on the subject; and it is to him that we are indebted for almost all the facts known concerning the composition of muscle. Some additions have also been made by Mr Fourcroy.

It is scarcely possible to separate the muscle from all the other substances with which it is mixed. A quantity of fat often adheres to it closely; blood pervades the whole of it: and every fibre is enveloped in a particular thin membranous matter, which anatomists distinguish by the name of *cellular substance*. The analysis of the muscle, then, cannot be supposed to exhibit an accurate view of the composition of pure muscular fibres, but only of muscular fibre not perfectly separated from other substances.

Action of cold water on muscle.

1. When a muscle is cut in small pieces, and well washed with water, the blood and other liquids contained in it are separated, and part of the muscular substance also is dissolved. The muscle, by this process, is converted into a white fibrous substance, still retain-

Chap. II.

ng the form of the original body. The water assumes
he colour which results from mixing water with some
lood. When heated it coagulates, brown flakes swim
n the surface, consisting of albumen combined with
he colouring matter of the blood; some fibrina like-
vise precipitates. If the evaporation be continued,
nore albumen precipitates, and at last the whole as-
umes the form of a jelly. When evaporated to dry-
ess, and treated with alcohol, the gelatine thus form-
d, together with a little phosphat of soda and of ammo-
ia, remain undissolved; but the alcohol dissolves a pe-
uliar *extractive* matter, first observed by Thouvenel.
his matter may be obtained by evaporating the alcohol
o dryness. It has a reddish brown colour, a strong
crid taste, and an aromatic odour. It is soluble both
n water and alcohol; and when its watery solution is
ery much concentrated, it assumes an acid and bitter
aste. It swells upon hot coals, and melts, emitting an
cid and penetrating smell. It attracts moisture from
e air, and forms a saline efflorescence. In a hot atmo-
phere it becomes sour and putrefies. When distilled
yields zoonic acid and zoonat of ammonia. All these
roperties render it probable that this substance of Mr
houvenel is that which is converted into *zoonic* acid
uring the roasting of meat.

Action of hot water.

2. If the muscle, after being thus treated with cold
ater, be boiled for a sufficient time in water, an addi-
onal portion of the same substances are separated from
. Some albumen collects on the surface in the form
f scum, accompanied with some melted fat. The wa-
r, when sufficiently concentrated by evaporation, as-
umes the form of a jelly. When evaporated to dry-
ess, and treated with alcohol, the gelatine and phos-

phoric salts remain, while the extractive matter of Thouvenel is dissolved, and may be obtained by evaporating to dryness. It is by this process that it is procured in a sufficient quantity for examination, cold water abstracting only a very small portion from the muscle.

Insoluble part fibrina.

3. The muscle, thus treated with water, is left in the state of grey fibres, insoluble in water, and becoming brittle when dry. This substance possesses all the properties of *fibrina*.

Composition of muscles.

4. From these facts, ascertained by Thouvenel and Fourcroy *, it appears that the muscles are composed chiefly of fibrina, to which they owe their fibrous structure and their form, and that they contain also

2. Albumen,	5. Phosphat of soda,
3. Gelatine.	6. Phosphat of ammonia,
4. Extract,	7. Phosph. of lime and carb. of ditto.

For the discovery of the last ingredients we are indebted to Mr Hatchett, who found that 500 parts of beef muscle left, after combustion, a residuum of 25.6 parts, consisting chiefly of these salts. We are still ignorant of the nature of the difference in the composition of the muscles of different animals, though a bare inspection is sufficient to convince us that such a difference exists; for the muscles of quadrupeds, of birds, and of fishes, neither resemble each other in their appearance nor taste.

When meat is boiled, it is obvious that the gelatine, the extract, and a portion of the salts, will be separated, while the coagulated albumen and fibrina will remain in a solid state. Hence the flavour and the nourishing nature of soups derived from the extract and gelatine.

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* Fourcroy, ix. 242.

Vhen meat is roasted, on the other hand, all these subtances continue in it, and the taste and odour of the xtract is greatly heightened by the action of the fire. Ience the superior flavour of roasted meat. Fourcroy upposes that the brown crust which forms on roasted neat is composed entirely of the extract.

SECT. III.

OF MEMBRANES, TENDONS, LIGAMENTS, AND GLANDS.

THESE substances have not hitherto been subjected to chemical analysis; their composition, of course, is but nperfectly known. Mr Hatchett has ascertained that hey contain no phosphat of lime as a constituent part, nd scarcely any saline ingredients; for when calcined hey leave but a very inconsiderable residuum. Thus 50 grains of hog's bladder left only 0.02 grain of reiduum *.

Membranes

1. The membranes are thin semitransparent bodies hich envelope certain parts of the body, especially the iscera; such as, the dura and pia mater, the pleura, he peritoneum, the periosteum, &c. These substances re soft and pliable; when macerated in water they swell, nd become somewhat pulpy; and by continued decocion in hot water they are almost completely dissolved, nd the solution concretes into gelatine. From the exeriments of Hatchett, we may conclude that the memranes are composed chiefly of coagulated albumen.

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* *Phil. Trans.* 1799. p. 333.

Tendons.

2. The tendons are strong, pearl-coloured, brilliant bodies, which terminate the muscles, and attach them to the bones, and are known in common language by the name of sinews. When boiled they assume the form of a semitransparent gelatinous substance, of a pleasant taste, well known in boiled meat. If the decoction be continued they dissolve completely, and are converted into gelatine.

Ligaments.

3. The ligaments are strong bands which bind the bones together at the different joints: they are fibrous substances, very dense and strong, and somewhat elastic: When boiled they yield a portion of gelatine, but they resist the action of water with great obstinacy, and after a great deal of boiling retain their form, and even their strength.

Glands.

4. The glands are a set of bodies employed to form or to alter the different liquids which are employed for different purposes in the animal body. There are two sets of them; the *conglobate*, which are small, scattered in the course of the lymphatics; and the *conglomerate*, such as the liver, kidneys, &c. Fourcroy supposes the first of these to be composed of gelatine; but this is not very probable. The structure of the large glands has been examined by anatomists with great care; but we are still ignorant of their composition. Indeed the present state of chemistry scarcely admits of an accurate analysis of these complicated bodies.

The membranes and tendons, especially the first, are usually employed in the manufacture of glue.

SECT. IV.

OF THE SKIN.

THE skin is that strong thick covering which envelopes the whole external surface of animals. It is composed chiefly of two parts: a thin white elastic layer on the outside, which is called *epidermis*, or *cuticle*; and a much thicker layer, composed of a great many fibres, closely interwoven, and disposed in different directions; this is called the *cutis*, or *true skin*. The *epidermis* is that part of the skin which is raised in blisters.

Epidermis.

1. The epidermis is easily separated from the cutis by maceration in hot water. It possesses a very great degree of elasticity.

It is totally insoluble in water and in alcohol. Pure fixed alkalies dissolve it completely, as does lime likewise, though slowly[*]. Sulphuric and muriatic acids do not dissolve it, at least they have no sensible action on it for a considerable time; but nitric acid soon deprives it of its elasticity, causes it to fall to pieces, and soon decomposes it[†].

It is well known that the living epidermis is tinged yellow almost instantaneously by nitric acid; but this effect does not take place, at least so speedily, when the dead cuticle is plunged in nitric acid altogether[‡].

True skin.

2. The cutis is a thick dense membrane, composed of

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[*] Chaptal, *Ann. de Chim.* xxii. 221.

[†] Cruikshank on *Insensible Perspiration*, p. 32.

[‡] Ibid.

Book V.

fibres interwoven like the texture of a hat. When it is macerated for some hours in water, and agitation and pressure is employed to accelerate the effect, the blood, and all the extraneous matter with which it was loaded, are separated from it, but its texture remains unaltered. On evaporating the water employed, a small quantity of gelatine may be obtained. No subsequent maceration in cold water has any farther effect. When distilled it yields the same products as fibrina. The concentrated alkalies dissolve it, converting it into oil and ammonia. Weak acids soften it, render it transparent, and at last dissolve it. Nitric acid converts it into oxalic acid and fat, while, at the same time, azotic gas and prussic acid are emitted *. When heated it contracts, and then swells, exhales a fetid odour, and leaves a dense charcoal, difficult to incinerate. By spontaneous decomposition in water or moist earth, it is converted into a fatty matter and into ammonia, which compose a kind of soap †.

When allowed to remain long in water, it softens and putrefies, being converted into a kind of jelly. When long boiled in water it becomes gelatinous, and dissolves completely, constituting a viscid liquor, which, by proper evaporation, is converted into glue. Hence the cutis of animals is commonly employed in the manufacture of glue. Thus it appears that the cutis contains a portion of gelatine ready formed, and that it may be totally converted into gelatine by boiling. It is therefore composed of gelatine and a fibrous matter. This last substance, according to Seguin, to whom we are indebted for a very ingenious set of experiments on the cutis,

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* Fourcroy, ix. 254.

† Ibid.

differs from gelatine merely in containing oxygen. This oxygen, according to him, is separated by the boiling, and of course the whole cutis assumes the form of gelatine.

Theory of tanning.

It is from the skin or cutis of animals that leather is formed. The process of converting skin into leather is called *tanning*. This process, though practised in the earliest ages, was merely empyrical, till the happy ingenuity of Mr Seguin led him to discover its real nature. After the epidermis, the gelatine, and all the impurities of the skin have been separated, after its fibres have been thickened, and its pores have been so far opened as to admit of being completely penetrated, it is steeped in an infusion of oak-bark, which consists of gallic acid and tan. The gallic acid (if we believe Seguin) deprives the skin gradually of oxygen, and thus makes it approach towards the state of gelatine, and the tan combines with this new substance the instant it is formed; and this process goes on so slowly that the texture of the skin is not altered. Leather, therefore, is merely a combination of tan with the fibrous part of the skin deprived of a part of its oxygen, and reduced nearly to the state of gelatine.

Difference in the cutis of animals.

The difference which is conspicuous in the cutis of different animals, seems to depend upon the relative proportions of the gelatine and fibrous oxide of which they are composed. In the skin of fishes and amphibious animals the gelatine abounds: Hence the facility with which they dissolve in water, and the brittleness of the leather which is formed from them. On the other hand, the fibrous oxide abounds in the skins of quadrupeds and birds: Hence the difficulty of dissolving them in hot water, and the excellent leather which they yield when tanned [*].

Rete mucosum.

3. As to the rete mucosum, or the mucous substance, situated between the cutis vera and epidermis, its composition cannot be determined with precision, because its quantity is too small to admit of examination. It is known that the black colour of negroes depends upon a black pigment, situated in this substance. Oxy-muriatic acid deprives it of its black colour, and renders it yellow. A negro, by keeping his foot for some time in water impregnated with that acid, deprived it of its colour, and rendered it nearly white; but in a few days the black colour returned again with its former intensity [†].

SECT. V.

OF THE BRAIN AND NERVES.

The brain and nerves are the instruments of sensation, and even of motion; for an animal loses the power of moving a part the instant that the nerves which enter it are cut.

The brain and nerves have a strong resemblance to each other; and it is probable that they agree also in their composition. But hitherto no attempt has been made to analyse the nerves. The only chemists who have examined the nature of *brain* are Mr Thouret [‡] and Mr Fourcroy [§].

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[*] Fourcroy, ix. 258.

[†] Ibid. p. 259.

[‡] *Jour. de Phys.* xxxviii. 329.

[§] *Ann. de Chim.* xvi. 282.

Chap. II.

Properties of brain.

The brain consists of two substances, which differ from each other somewhat in colour, but which, in other respects, seem to be of the same nature. The outermost matter, having some small resemblance in colour to wood-ashes, has been called the *cineritious* part; the innermost has been called the *medullary* part.

Brain has a soft feel, not unlike that of soap; its texture appears to be very close; its specific gravity is greater than that of water.

When brain is kept in close vessels so that the external air is excluded, it remains for a long time unaltered: Fourcroy filled a glass vessel almost completely with pieces of brain, and attached it to a pneumatic apparatus; a few bubbles of carbonic acid gas appeared at first, but it remained above a year without undergoing any farther change *.

This is very far from being the case with brain exposed to the atmosphere. In a few days (at the temperature of 60°) it exhales a most detestable odour, becomes acid, assumes a green colour, and very soon a great quantity of ammonia makes its appearance in it.

Action of cold water,

Cold water does not dissolve any part of the brain; but by trituration in a mortar, it forms, with water, a whitish-coloured emulsion, which appears homogenous, may be passed through a filter, and the brain does not precipitate by rest. When this emulsion is heated to 145°, a white coagulum is formed. The addition of a great quantity of water also causes a coagulum to appear, which swims on the surface, but the water still retains a milky colour. When sulphuric acid is dropt into the watery emulsion of brain, white flakes separate

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* *Ann. de Chim.* xvi. 297.

and swim on the surface, and the liquid becomes red. Nitric acid produces the same effects, only the liquid becomes yellow. Alcohol also separates a white coagulum from the emulsion, after it has been mixed with it for some hours. When nitric acid is added to the emulsion till it becomes slightly acid, a coagulum is also separated. This coagulum is of a white colour; it is insoluble in water and in alcohol. Heat softens, but does not melt it. When dried, it becomes transparent, and breaks with a glassy fracture. It has therefore some resemblance to *albumen* *.

Of sulphuric acid,

When brain is triturated in a mortar with diluted sulphuric acid, part is dissolved, the rest may be separated, by filtration, in the form of a coagulum. The acid liquor is colourless. By evaporation, the liquid becomes black, sulphurous acid is exhaled, and crystals appear; and when evaporated to dryness, a black mass remains behind. When this mass is diluted with water, a quantity of charcoal separates, and the water remains clear. The brain is completely decomposed, a quantity of ammonia combines with the acid and forms sulphat of ammonia, while charcoal is precipitated. The water, by evaporation and treatment with alcohol, yields sulphats of ammonia and lime, phosphoric acid, and phosphats of soda and ammonia. Brain therefore contains

Phosphat of lime
———— soda
———— ammonia.

Traces also of sulphat of lime can be discovered in it. The quantity of these salts is very small; altogether they do not amount to $\frac{1}{110}$th part †.

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* *Ann. de Chim.* xvi. 288.

† Ibid.

Of nitric acid,

Diluted nitric acid, when triturated with brain, likewise dissolves a part, and coagulates the rest. The solution is transparent. When evaporated till the acid becomes concentrated, carbonic acid gas and nitrous gas are disengaged; an effervescence takes place, white fumes appear, an immense quantity of ammonia is disengaged, a bulky charcoal remains mixed with a considerable quantity of oxalic acid *.

When brain is gradually evaporated to dryness by the heat of a water bath, a portion of transparent liquid separates at first from the rest, and the residuum, when nearly dry, acquires a brown colour; its weight amounts to about one-fourth of the fresh brain. It may still be formed into an emulsion with water, but very soon separates again spontaneously.

Of alcohol,

When alcohol is repeatedly boiled upon this dried residuum till it ceases to have any more action, it dissolves about five-eighths of the whole. When this alcohol cools, it deposites a yellowish white substance, composed of brilliant plates. When kneaded together by the fingers, it assumes the appearance of a ductile paste: at the temperature of boiling water it becomes soft, and when the heat is increased it blackens, exhales empyreumatic and ammoniacal fumes, and leaves behind it a charry matter †. When the alcohol is evaporated, it deposites a yellowish black matter, which reddens paper tinged with turnsole, and readily diffuses itself through water ‡.

Of Potass.

Pure concentrated potass dissolves brain, disengaging a great quantity of ammonia.

These facts are sufficient to shew us, that, exclusive

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* *Ann. de Chim.* xvi. 307. † Ibid. 313. ‡ Ibid. 317.

Composition of brain,

of the small proportion of saline ingredients, brain is composed of a peculiar matter, differing in many particulars from all other animal substances, but having a considerable resemblance in many of its properties to albumen. Brain has been compared to a soap; but it is plain that the resemblance is very faint, as scarcely any oily matter could be extricated from brain by Fourcroy, though he attempted it by all the contrivances which the present state of chemistry suggested; and the alkaline proportion of it is a great deal too small to merit any attention.

SECT. VI.

OF NAILS, HORNS, HAIR, AND FEATHERS.

THESE substances have not been hitherto analysed by chemists, of course we are but imperfectly acquainted with their composition.

Nails,

1. The nails which cover the extremities of the fingers are attached to the epidermis, and come off along with it. Mr Hatchett has ascertained that they are composed chiefly of a membranous substance, which possesses the properties of coagulated albumen. They seem to contain also a little phosphat of lime. Water softens, but does not dissolve them. But they are readily dissolved and decomposed by concentrated acids and alkalies.

Horns,

2. The horns and hoofs of quadrupeds resemble the nails in their properties, and are doubtless composed of the same ingredients, though this has not been ascer-

tained by experiment. It is scarcely necessary to describe the products obtained by distilling them, as this yields but little additional information. They scarcely contain any earthy ingredients. One hundred grains of ox horn, after calcination, left only 0.04 grain of residuum, half of which was phosphat of lime. Seventy-eight grains of chamois horn left five grains of residuum *.

Hair,

3. Hair resembles the preceding substances in several of its properties; but it is much more combustible, and approaches the oils in its inflammability. When distilled, 1152 parts of hair yielded Berthollet the following products:

90	carbonat of ammonia
179	water smelling of burnt hair
288	oil
271	gases
324	coal
1152	

The oil was of a brown colour, solid unless exposed to a heat equal to 73°, very soluble in alcohol, burnt with great briliancy, and with scintillations like hair. The charcoal was difficult to incinerate, and was attracted by the magnet; of course it contained iron. It probably also contains phosphat of lime.

Water softens hair but does not melt it. Oxy-muriatic acid whitens it, or if the hair be plunged into that acid in the state of gas, it reduces it to a pulp, and dissolves and decomposes it completely. Nitric acid tinges it yellow. Hair is dissolved by the alkalies, and is converted into a kind of soap. When muriatic acid is

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* Hatchett, *Phil. Trans.* 1799. p. 332.

poured into this solution, a quantity of sulphurated hydrogen gas is disengaged, and a black substance, doubtless charcoal, precipitates. Hence it follows that it contains sulphur. Accordingly, if a bit of silver is put into the solution, it instantly assumes a black colour *.

Feathers.

4. Feathers seem to possess very nearly the same properties with hair. Mr Hatchett has ascertained that the quill is composed chiefly of coagulated albumen.

Having given the preceding account of the solids which compose animal bodies, I proceed next to the fluid which circulates through living bodies, namely *blood*; and to the various *secretions* formed from the blood, either in order to answer some important purpose to the animal, or to be evacuated as useless, that the blood thus purified may be more proper for answering the ends for which it is destined. Many of these substances have been examined with more care by chemists than the animal solids.

SECT. VII.

OF BLOOD.

Properties of blood.

Blood is a well known fluid, which circulates in the veins and arteries of the more perfect animal. It is of a red colour, has a considerable degree of consistency, and an unctuous feel, as if it contained a quantity of soap. Its taste is slightly saline, and it has a peculiar smell.

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* Merat-Guillot, *Ann. de Chim.* xxxiv. 70.

The specific gravity of human blood is, at a medium, 1.0527[*]. Mr Fourcroy found the specific gravity of bullock's blood, at the temperature of 60°, to be 1.056[†]. The blood does not uniformly retain the same consistence in the same animal, and its consistence in different animals is very various. It is easy to see that its specific gravity must be equally various.

No substance has attracted a greater degree of attention than the blood. The number of philosophers who have devoted their time to develope its nature, and ascertain its properties, is immense. It was not, however, till towards the middle of the eighteenth century that much progress was made in its chemical analysis[‡]. The prussic acid formed during its decomposition had been observed; Hales had measured the gases exhaled during its distillation; Menghini had demonstrated the presence of iron in it; and several curious observations had been made upon its coagulation.—But Rouelle Junior was the first chemist who published a tolerably precise analysis of it. Since that time much additional information has been acquired by the experiments of Bucquet, Fourcroy, Deyeux, Parmentier, &c.

Spontaneous decomposition.

When blood, after being drawn from an animal, is allowed to remain for some time at rest, it very soon coagulates into a solid mass, of the consistence of curdled milk. This mass gradually separates into two parts: one of which is fluid, and is called *serum;* the other, the coagulum, has been called *cruor*, because it alone retains the red colour which distinguishes blood. This

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[*] Haller's *Physiology*, ii. 41.

[†] *Ann. de. Chim.* vii. 147.

[‡] A very full account of every thing that had been done before that time, may be found in the second volume of Haller's *Physiology*.

separation is very similar to the separation of curdled milk into curds and whey.

The proportion between the cruor and serum of the blood varies much in different animals, and even in the same animal in different circumstances. The most common proportion is about one part of cruor to three parts of serum; but in many cases the cruor exceeds and falls short of this quantity; the limits of the ratios of these substances to each other appear, from a comparison of the conclusions of most of those who have written accurately on the subject, to be 1 : 1 and 1 : 4; but the first case must be very rare indeed*.

The cause of this spontaneous decomposition of blood has not hitherto been ascertained. The coagulation takes place equally in close vessels and in the open air, whether the blood be allowed to cool, or be kept at the temperature at which it is when it issues from the animal; neither is the coagulation prevented by diluting it with water, as has been sufficiently proved by the experiments of Hewson, Hunter, Deyeux and Parmentier.

Serum

1. The serum is of a light greenish yellow colour; it has the taste, smell, and feel of the blood, but its consistence is not so great. Its mean specific gravity is about 1.0287 †. It converts syrup of violets to a green, and therefore contains an alkali. On examination, Rouelle found that it owes this property to a portion of soda. When heated to the temperature of 156°‡, the serum coagulates, as Harvey first discovered §. It coagulates also when boiling water is mixed with it; but if serum be mixed with six parts of cold water, it

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* Haller's *Physiology*, ii. 47.

† Jurin, Haller's *Physiology*, ii. 41.

‡ Cullen.

§ *De Gener. Anim.* p. 161.

does not coagulate by heat[*]. When thus coagulated, it has a greyish white colour, and is not unlike the boiled white of an egg[†]. If the coagulum be cut into small pieces, a muddy fluid may be squeezed from it, which has been termed the *serosity*. After the separation of this fluid, if the residuum be carefully washed in boiling water and examined, it will be found to possess all the properties of *albumen*. The serum, therefore, contains a considerable proportion of albumen. Hence its coagulation by heat, and the other phenomena which albumen usually exhibits.

Contains albumen,

If serum be diluted with six times its weight of water, and then boiled to coagulate the albumen, the liquid which remains after the separation of the coagulum, if it be gently evaporated till it becomes concentrated, and then be allowed to cool, assumes the form of a jelly, as was first observed by De Haen[‡]. Consequently it contains *gelatine*.

Gelatine,

If the coagulated serum be heated in a silver vessel, the surface of the silver becomes black, being converted into a sulphuret. Hence it is evident that it contains sulphur[§], and Proust has ascertained that it is combined with ammonia in the state of a hydrosulphuret.

Sulphur,

If serum be mixed with twice its weight of water, and, after coagulation by heat, the albumen be separated by filtration, and the liquid be slowly evaporated till it is considerably concentrated, a number of crystals are deposited when the liquid is left standing in a cool place. These crystals, first examined by Rouelle, consist of carbonat of soda, muriat of soda, besides phos-

And salts

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[*] Fourcroy, *Ann. de Chim.* vii. 157.

[†] Ibid. 156.

[‡] Ibid. 157.

[§] Deyeux and Parmentier, *Jour. de. Phys.* xliv. 437.

phat of soda, and phosphat of lime. The soda exists in the blood in a caustic state, and seems to be combined with the gelatine and albumen. The carbonic acid combines with it during evaporation.

Thus it appears that the serum of the blood contains albumen, gelatine, hydrosulphuret of ammonia, soda, muriat of soda, phosphat of soda, and phosphat of lime. These component parts account for the coagulation occasioned in the serum by acids and alcohol, and the precipitation produced by tan, acetite of lead, and other metallic salts.

Cruor contains fibrina,

2. The cruor, or *clot* as it is sometimes called, is of a red colour, and possesses considerable consistence. Its mean specific gravity is about 1.245[*]. If this cruor be washed carefully by letting a small jet of water fall upon it, till the water runs off colourless, it is partly dissolved, and partly remains upon the searce. Thus it is separated into two portions; namely, 1. A white, solid, elastic substance, which has all the properties of *fibrina*. 2. The portion held in solution by the water; which consists of the colouring matter, not however in a state of purity, for it is impossible to separate the cruor completely from the serum.

We are indebted to Bucquet for the first precise set of experiments on this last watery solution. It is of a red colour. Bucquet proved that it contained albumen and iron. Menghini had ascertained, that if blood be evaporated to dryness by a gentle heat, a quantity of iron may be separated from it by the magnet. The quantity which he obtained was considerable; according to him, the blood of a healthy man contains above

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[*] Jurin, Haller's *Physiology*, ii. 41.

two ounces of it. Now, as neither the serum nor the fibrina extracted from the cruor contain iron, it follows of course, that the water holding the colouring matter in solution must contain the whole of that metal.

Albumen,

This watery solution gives a green colour to syrup of violets. When exposed to the air, it gradually deposites flakes, which have the properties of albumen. When heated, a brown-coloured scum gathers on its surface. If it be evaporated to dryness, and then mixed with alcohol, a portion is dissolved, and the alcoholic solution yields by evaporation a residuum, which lathers like soap in water, and tinges vegetable blues green; the acids occasion a precipitate from its solution. This substance is a compound of albumen and soda. Thus we see that the watery solution contains albumen, iron, and soda.

Soda,

Sub-phosphat of iron.

Fourcroy and Vauquelin have ascertained that the iron is combined with phosphoric acid, and in the state of sub-phosphat of iron; thus confirming an opinion which had been maintained by Sage, and announced as a fact by Gren. If the residuum obtained by evaporating the watery solution of the colouring matter of blood to dryness be burnt in a crucible, there will remain a deep red ferruginous substance, amounting to 0.045 of the blood employed. Nitric acid digested on this residuum dissolves a portion, which is phosphat of iron, and is precipitated white by ammonia, but aſsumes a red colour when treated with pure potass. When lime-water is poured into the potass employed, phosphat of lime precipitates. By this treatment they ascertained, that $\frac{10}{26}$ of the residuum consisted of sub-phosphat of iron. Now phosphat of iron is soluble in acids, but insoluble in water; when treated with pure alkalies, it loses a portion of its acid, assumes a red colour, and is converted into sub-phosphat. Hence it is evidently the soda of the blood which reduces it to that state, or at least maintains it in that state. Sub-phosphat of iron readily dissolves in albumen and in serum *.

3. When new drawn blood is stirred briskly round with a stick, or the hand, the whole of the fibrina collects together upon the stick, and in this manner may be separated altogether from the rest of the blood. The red globules, in this case, remain behind in the serum. It is in this manner that the blood is prepared for the different purposes to which it is put; as clarifying sugar, making puddings, &c. After the fibrina is thus separated, the blood no longer coagulates when allowed to remain at rest, but a spongy flaky matter separates from it, and swims on the surface †.

Action of heat on blood.

When blood is dried by a gentle heat, water exhales from it, retaining a very small quantity of animal matter in solution, and consequently having the odour of blood. Blood dried in this manner being introduced into a retort and distilled, there comes over, first a clear watery liquor, then carbonic acid gas, and carbonat of ammonia, which crystallizes in the neck of the retort; after these products there comes over a fluid oil, carbonated hydrogen gas, and an oily substance of the consistence of butter. The watery liquor possesses the property of precipitating from sulphat of iron a green powder: muriatic acid dissolves part of this powder, and there remains behind a little prussian blue. Consequently this watery liquor contains both an alkali and prussic acid ‡.

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* Fourcroy, ix. 152.

† Fourcroy, *Ann. de Chim.* vii. 146.

‡ Ibid. 153.

9216 grains of dried blood being put into a large crucible, and gradually heated, at first became nearly fluid, and swelled up considerably, emitted a great many fetid fumes of a yellowish colour, and at last took fire and burned with a white flame, evidently owing to the presence of oil. After the flame and the fumes had disappeared, a light smoke was emitted, which affected the eyes and the nose, which had the odour of prussic acid, and reddened moist papers stained with vegetable blues. At the end of six hours, when the matter had lost five-sixths of its substance, it melted anew, exhibited a purple flame on its surface, and emitted a thick smoke. This smoke affected the eyes and nostrils, and reddened blue paper, but it had not the smell of prussic acid. When a quantity of it was collected and examined, it was found to possess the properties of phosphoric acid. The residuum amounted to 181 grains; it had a deep black colour, and a metallic brilliancy; and its particles were attracted by the magnet. It contained no uncombined soda, though the blood itself, before combustion, contains it abundantly; but water extracted from it muriat of soda: part of the remainder was dissolved by muriatic acid, and of course was lime; there was besides a little silica, which had evidently been separated from the crucible. The iron had been reduced during the combustion *.

Component parts of blood.

Such are the properties of blood, as far as they have been hitherto ascertained by experiment. We have seen that it contains the following ingredients:

1. Water,
3. Albumen,
2. Fibrina,
4. Gelatine,

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* Fourcroy, *Ann. de Chim.* vii. 151.

5. Hydrosulphuret of ammonia,
6. Soda,
7. Sub-phosphat of iron,
8. Muriat of soda,
9. Phosphat of soda,
10. Phosphat of lime.

Besides benzoic acid, which has been detected by Proust.

4. But our knowledge of this singular fluid is by no means so complete as it ought to be; a more accurate analysis would probably discover the presence of other substances, and enable us to account for many of the properties of blood which at present are inexplicable.

It would be of great consequence also to compare together the blood of different animals, and of the same animal at different ages, and to ascertain in what particulars they differ from each other. This would probably throw light on some of the obscurest parts of the animal economy. Very little progress has hitherto been made in these researches. If we except the labours of Rouelle, who obtained nearly the same ingredients, though in different proportions, from the blood of a great variety of animals, the experiments of Fourcroy on the blood of the human fœtus are almost the only ones of that kind with which we are acquainted.

Blood of the fœtus.

He found that it differs from the blood of the adult in three things 1. Its colouring matter is darker, and seems to be more abundant; 2. It contains no fibrina, but probably a greater proportion of gelatine than blood of adults; 3. It contains no phosphoric acid *.

The examination of diseased blood, too, would be of great consequence; because the difference of its properties from the blood of people in health might throw much light on the nature of the disease.

Deyeux and Parmentier, to whom we are indebted

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* Fourcroy, *Ann. de Chim.* vii. 162.

for an excellent analysis of blood, examined that liquid drawn from patients labouring under different diseases; but the result of their examination was not so satisfactory as might have been expected.

Diseased blood.

1. It has been long known, that blood drawn from a person labouring under inflammation, is soon covered with a white crust, which is distinguished by physicians by the name of *the buffy coat*, and which characterises blood during inflammation. Deyeux and Parmentier ascertained that this buffy coat consists of the fibrina. The cruor deprived of this substance is much softer than usual, and almost totally soluble in water. The albumen of the serum is also altered, for it does not coagulate as usual when heated, but becomes milky when mixed with hot water.

2. The blood drawn from several patients labouring under sea scurvy, afforded scarcely any remarkable properties to these chemists, except a peculiar smell, and an albumen which was not so easily coagulated as usual.

3. The blood drawn from patients afflicted with a putrid fever was also examined by these chemists. Sometimes it exhibited the inflammatory crust, but frequently it did not appear to differ from healthy blood *.

4. During that disease which is known by the name of *diabetes*, in which the urine is excessive in quantity, and contains sugar, the serum of blood often, as appears from the experiments of Dr Dobson and Dr Rollo, assumes the appearance of whey; and, like it, seems to contain sugar, or at least it has lost it usual salt taste.

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* *Jour. de Phys.* xliv. 454.

SECT. VIII.

OF MILK.

Milk is a fluid secreted by the female of all those animals denominated *mammalia*, and intended evidently for the nourishment of her offspring.

The milk of every animal has certain peculiarities which distinguish it from every other milk. But the animal whose milk is most made use of by man as an article of food, and with which, consequently, we are best acquainted, is the *cow*. Chemists, therefore, have made choice of cow's milk for their experiments. I shall at first confine myself to the properties and analysis of cow's milk, and afterwards point out in what respect the milk of other animals differs from it, as far at least as these differences have hitherto been ascertained.

Properties of milk.

Milk is an opaque fluid, of a white colour, a slight peculiar smell, and a pleasant sweetish taste. When newly drawn from the cow, it has a taste very different from that which it acquires after it has been kept for some hours.

It is liquid, and wets all those substances which can be moistened by water; but its consistence is greater than that of water, and it is slightly unctuous. Like water, it freezes when cooled down to about 30°; but Parmentier and Deyeux, to whom we are indebted for by far the completest account of milk hitherto published, found that its freezing point varies considerably in the milk of different cows, and even of the same cow at different times *. Milk boils also when sufficiently heated; but the same variation takes place in the boiling point of different milks, though it never deviates very far from the boiling point of water. Milk is specifically heavier than water, and lighter than blood; but the precise degree cannot be ascertained, because almost every particular milk has a specific gravity peculiar to itself.

Spontaneous decomposition.

When milk is allowed to remain for some time at rest, there collects on its surface a thick unctuous yellowish coloured substance, known by the name of *cream*. The cream appears sooner in milk in summer than in winter, evidently owing to the difference of temperature. In summer, about four days of repose are necessary before the whole of the cream collects on the surface of the liquid; but in winter it requires at least double the time †.

After the cream is separated, the milk which remains is much thinner than before, and it has a bluish white colour. If it be heated to the temperature of 100°, and a little *rennet*, which is water digested with the inner coat of a calf's stomach, and preserved with salt, be poured into it, coagulation ensues; and if the coagulum be broken, the milk very soon separates into two substances; a solid white part, known by the name of *curd*, and a fluid part called *whey*.

Thus we see that milk may be easily separated into three parts; namely, *cream*, *curd*, and *whey*.

Cream

1. Cream is of a yellow colour, and its consistence increases gradually by exposure to the atmosphere. In

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* *Jour. de Phys.* xxxviii. 362.

† Fourcroy, *Ann. de Chim.* vii. 167.

three or four days, it becomes so thick that the vessel which contains it may be inverted without risking any loss. In eight or ten days more, its surface is covered over with mucors and byssi, and it has no longer the flavour of cream, but of very fat cheese[*]. This is the process for making what in this country is called a *cream cheese*.

Cream possesses many of the properties of an oil. It is specifically lighter than water, it has an unctuous feel, stains clothes precisely in the manner of oil; and if it be kept fluid, it contracts at last a taste which is very analogous to the rancidity of oils [†]. When kept boiling for some time, a little oil makes its appearance, and floats upon its surface [‡]. Cream is neither soluble in alcohol nor oils [§]. These properties are sufficient to shew us that it contains a quantity of oil; but this oil is combined with a part of the curd, and mixed with some serum. Cream, then, is composed of a peculiar oil, curd, and serum. The oil may be easily obtained separate by agitating the cream for a considerable time. This process, known to every body, is called *churning*. After a certain time, the cream separates into two portions: one fluid, and resembling creamed milk; the other solid, and called *butter*.

Converted into butter.

Butter is of a yellow colour, possesses the properties of an oil, and mixes readily with other oily bodies. When heated to the temperature of 96°, it melts, and becomes transparent; if it be kept for some time melted, some curd and water or whey separate from it, and it assumes exactly the appearance of oil [||]. But this

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[*] Parmentier and Deyeux, *Jour. de Phys.* xxxviii. 372.

[†] Ibid. 375. [‡] Ibid. 374. [§] Ibid.

[||] Fourcroy, *Anu de Chim.* vii. 170.

process deprives it in a great measure of its peculiar lavour.

When butter is kept for a certain time, it becomes ancid, owing in a good measure to the presence of hese foreign ingredients; for if butter be well washed, nd a great portion of these matters separated, it does not become rancid nearly so soon as when it is not treatd in this manner. It was formerly supposed that this ancidity was owing to the developement of a peculiar cid; but Parmentier and Deyeux have shewn that no cid is present in rancid butter *. When butter is ditilled, there comes over water, sebacic acid, and oil, at irst fluid, but afterwards concrete. The carbonaceous esiduum is but small.

Nature of this change.

Butter may be obtained by agitating cream newly aken from milk, or even by agitating milk newly drawn rom the cow. But it is usual to allow cream to renain for some time before it is churned. Now cream, by standing, acquires a sour taste; butter therefore is commonly made from sour cream. Fresh cream requires at least four times as much churning before it yields its utter as sour cream does †; consequently cream acquires, by being kept for some time, new properties, in consequence of which it is more easily converted into butter. When very sour cream is churned, every one who has paid the smallest attention must have perceived, hat the butter milk, after the churning, is not nearly so sour as the cream had been. The butter, in all cases, s perfectly sweet; consequently the acid which had been evolved has in a great measure disappeared during the process of churning. It has been ascertained, that

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[*] Fourcroy, *Ann. de Chim.* vii. 375.

[†] Ibid. 169,

Book V.

cream may be churned, and butter obtained, though the contact of atmospheric air be excluded *. I have no doubt, that in all cases where such an experiment succeeded, the cream on which it was made had previously become sour. On the other hand, it has been ascertained, that when cream is churned in contact with air, it absorbs a considerable quantity of it †; and it cannot be doubted that the portion absorbed is oxygen.

These facts are sufficient to afford us a key to explain what takes place during the process of churning. There is a peculiar oil in milk, which has so strong an affinity for the other ingredients, that it will not separate from them spontaneously; but it has an affinity for oxygen, and when combined with it, forms the concrete body called *butter*. Agitation produces this combination of the oil with oxygen; either by causing it to absorb oxygen from the air, or, if that be impossible, by separating it from the acid which exists in sour cream. Hence the absorption of air during churning; hence also the increase of temperature of the cream, which Dr Young found to amount constantly to 4°; and hence the sweetness of the butter-milk compared with the cream from which it was obtained.

The affinity of the oil of cream for the other ingredients is such, that it never separates completely from them. Not only is curd and whey always found in the cream, but some of this oil is constantly found in creamed milk and even in whey: for it has been ascertained by actual experiment, that butter may be obtained by churning whey; 27 Scotch pints of whey yield at an average about a pound of butter ‡. This accounts for

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* Young, *de Lacte*, 15.

† *Mid-Lothian Report for* 1795.

‡ Ibid.

a fact well known to those who superintend dairies, that a good deal more butter may be obtained from the same quantity of milk, provided it be churned as drawn from the cow, than when the cream alone is collected and churned.

The butter-milk, as Parmentier and Deyeux ascertained by experiment, possesses precisely the properties of milk deprived of cream *.

Properties of curd.

2. CURD, which may be separated from creamed milk by rennet, has all the properties of coagulated albumen. It is white and solid; and when all the moisture is squeezed out, it has a good deal of bitterness. It is insoluble in water; but pure alkalies and lime dissolve it readily, especially when assisted by heat; and when fixed alkali is used, a great quantity of ammonia is emitted during the solution. The solution of curd in soda is of a red colour, at least if heat be employed; owing probably to the separation of charcoal from the curd by the action of the alkali †. Indeed, when a strong heat has been used, charcoal precipitates as the solution cools ‡. The matter dissolved by the alkali may be separated from it by means of an acid; but it has lost all the properties of curd. It is of a black colour, melts like tallow by the application of heat, leaves oily stains on paper, and never acquires the consistence of curd §. Hence it appears that curd, by the action of a fixed alkali, is decomposed, and converted into two new substances, ammonia, and oil or rather fat.

Curd is soluble also in acids. If, over curd newly precipitated from milk, and not dried, there be poured

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* *Jour. de Phys.* xxxviii. 379.

† Ibid.

‡ Foucroy, Ibid. p. 175.

§ Ibid.

eight parts of water, containing as much of any of the mineral acids as gives it a sensibly acid taste, the whole is dissolved after a little boiling *. Acetous acid and lactic acid do not dissolve curd when very much diluted †. But these acids, when concentrated, dissolve it readily, and in considerable quantity ‡. It is remarkable enough, that concentrated vegetable acids dissolve curd readily, but have very little action on it when they are very much diluted: whereas the mineral dissolve it when much diluted; but when concentrated, have either very little effect on it, as sulphuric acid §; or decompose it, as nitric acid. By means of this last acid, as Berthollet discovered, a quantity of azotic gas may be obtained from curd.

Of cheese.

Curd, as is well known, is used in making *cheese;* and the cheese is the better the more it contains of cream, or of that oily matter which constitutes cream. It is well known to cheesemakers, that the goodness of it depends in a great measure on the manner of separating the whey from the curd. If the milk be much heated, the coagulum broken in pieces, and the whey forcibly separated, as is the practice in many parts of Scotland, the cheese is scarce good for any thing; but the whey is delicious, especially the last squeezed out whey, and butter may be obtained from it in considerable quantity. A full proof that nearly the whole creamy part of the milk has been separated with the whey. Whereas if the milk be not too much heated (about 100° is sufficient), if the coagulum be allowed

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[*] Scheele, ii. 53.

[†] Ibid.

[‡] Parmentier and Deyeux, *Jour. de Phys.* xxxviii. 417.—Fourcroy, Ibid. p. 173.

[§] Parmentier, Ibid.

o remain unbroken, and the whey be separated by very low and gentle pressure, the cheese is excellent; but he whey is almost transparent, and nearly colourless.

Good cheese melts at a moderate heat; but bad heese, when heated, dries, curls, and exhibits all the henomena of burning horn. Hence it is evident, that ll the properties in which curd differs from albumen re owing to its containing combined with it a quantity f the peculiar oil which constitutes the distinguishing haracteristic of cream; hence its flavour and smell, nd hence also the white colour of milk.

Coagulation of milk.

This sameness of curd and albumen shews us, that he coagulation of milk and of albumen depend upon he same cause. Heat, indeed, does not coagulate milk, ecause the albumen in it is diluted with too large a uantity of water; but if milk be boiled in contact vith air, a pellicle soon forms on its surface, which has he properties of coagulated albumen. If this pellicle be emoved, another succeeds; and by continuing the boilng, the whole of the albuminous or curdy matter may e separated from milk *. When this pellicle is allowd to remain, it falls at last to the bottom of the vessel, here, being exposed to a greater heat, it becomes rown, and communicates to milk that disagreeable aste which, in this country, is called a *singed* taste. It appens more readily when milk is boiled along with ice, flour, &c.

If to boiling milk there be added as much of any neual salt as it is capable of dissolving, or of sugar, or of um arabic, the milk coagulates, and the curd separates †.

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* Parmentier, *Jour. de Phys.* xxxviii. 415.

† Scheele, ii. 52.

Alcohol also coagulates milk [*]; as do all acids, rennet, and the infusion of the flowers of artichoke and of the thistle [†]. If milk be diluted with ten times its weight of water, it cannot be made to coagulate at all [‡].

Whey

3. Whey, after being filtered to separate a quantity of curd which still continues to float through it, is a thin pellucid fluid, of a yellowish green colour and pleasant sweetish taste, in which the flavour of milk may be distinguished. It always contains some curd; but nearly the whole may be separated by keeping the whey for some time boiling; a thick white scum gathers on the surface, which in Scotland is known by the name of *float whey*. When this scum, which consists of the curdy part, is carefully separated, the whey, after being allowed to remain at rest for some hours, to give the remainder of the curd time to precipitate, is decanted off almost as colourless as water, and scarcely any of the peculiar taste of milk can be distinguished in it.

Contains sugar of milk,

If it be now slowly evaporated, it deposites at last a number of white-coloured crystals, which are *sugar of milk*. Towards the end of the evaporation, some crystals of muriat of potass and of muriat of soda make their appearance [§]. According to Scheele, it contains also a little phosphat of lime [||], which indeed may be precipitated by ammonia.

Salts,

And gelatine.

After the salts have been obtained from whey, what remains concretes into a jelly on cooling [¶]. Hence it follows that whey also contains *gelatine*. Whey, then,

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[*] Parmentier, *Jour. de Phys.* xxxviii. 416.

[†] Ibid.

[‡] Scheele, ii. 54.

[§] Parmentier, *Jour. de Phys.* xxxviii. 417.

[||] Scheele, ii. 61.

[¶] Rouelle.

is composed of water, sugar of milk, gelatine, muriat of potass, and phosphat of lime. The other salts, which are sometimes found in it, are only accidentally present.

Becomes acid.

If whey be allowed to remain for some time, it becomes sour, owing to the formation of a peculiar acid known by the name of *lactic acid*. It is to this property of whey that we are to ascribe the acidity which milk contracts; for neither curd nor cream, perfectly freed from serum, seem susceptible of acquiring acid properties. Hence the reason also that milk, after it becomes sour, always coagulates. Boiled milk has the property of continuing longer sweet; but it is singular enough that it runs sooner to putrefaction than ordinary milk *.

May be converted into vinegar.

The acid of milk differs considerably from the acetous; yet vinegar may be obtained from milk by a very simple process. If to somewhat more than 8 lbs. troy of milk six spoonfuls of alcohol be added, and the mixture well corked be exposed to a heat sufficient to support fermentation (provided attention be paid to allow the carbonic acid gas to escape from time to time), the whey, in about a month, will be found converted into vinegar †.

Milk capable of the vinous fermentation.

Milk is almost the only animal substance which may be made to undergo the vinous fermentation, and to afford a liquor resembling wine or beer, from which alcohol may be separated by distillation. This singular fact seems to have been first discovered by the Tartars; they obtain all their spirituous liquors from mares milk. It has been ascertained, that milk is incapable of being

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* Parmentier, *Jour. de Phys.* xxxviii. 343.

† Scheele, ii. 68.

converted into wine till it has become sour; after this, nothing is necessary but to place it in the proper temperature; the fermentation begins of its own accord, and continues till the formation of wine be completed*. Scheele had observed, that milk was capable of fermenting, and that a great quantity of carbonic acid gas was extricated from it during this fermentation†. But he did not suspect, that the result of this fermentation was the formation of an intoxicating liquor similar to wine.

Distillation of milk.

When milk is distilled by the heat of a water-bath, there comes over water, having the peculiar odour of milk; which putrefies, and consequently contains, besides mere water, some of the other constituent parts of milk. After some time the milk coagulates ‡, as always happens when hot albumen acquires a certain degree of concentration. There remains behind a thick unctuous yellowish-white substance, to which Hoffman gave the name of *franchipann*. This substance, when the fire is increased, yields at first a transparent liquid, which becomes gradually more coloured; some very fluid oil comes over, then ammonia, an acid, and at last a very thick black oil. Towards the end of the process carbonated hydrogen gas is disengaged§. There remains in the retort a coal which contains carbonat of potass, muriat of potass, and phosphat of lime, and sometimes magnesia, iron, and muriat of soda ||.

Its composition.

Thus we see that cow's milk is composed of the following ingredients:

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[*] Parmentier, *Jour. de Phys.* xxxviii 365.

[†] Scheele, ii. 66.

[‡] Bouquet.

[§] Parmentier, *Jour. de Phys.* xxxviii. 368.

[||] *Mem. Med. Par.* 1787, p. 607.

1. Water,
2. Oil,
3. Albumen,
4. Gelatine,
5. Sugar of milk,
6. Muriat of soda,
7. Muriat of potass,
8. Sulphur
9. Phosphat of lime.

The milk of all other animals, as far as it has hitherto been examined, consists nearly of the same ingredients; but there is a very great difference in their proportion.

Woman's milk.

Woman's milk has a much sweeter taste than cow's milk. When allowed to remain at rest for a sufficient time, a cream gathers on its surface. This cream is more abundant than in cow's milk, and its colour is usually much whiter. After it is separated, the milk is exceedingly thin, and has the appearance rather of whey, with a bluish white colour, than of creamed milk. None of the methods by which cow's milk is coagulated succeed in producing the coagulation of woman's milk *. It is certain, however, that it contains curd; for if it be boiled, pellicles form on its surface, which have all the properties of curd †. Its not coagulating, therefore, must be attributed to the great quantity of water with which the curd is diluted.

Though the cream be churned ever so long, no butter can be obtained from it; but if, after being agitated for some hours, it be allowed to remain at rest for a day or two, it separates into two parts; a fluid which occupies the inferior part of the vessel, pellucid and colourless like water, and a thick white unctuous fluid, which swims on the surface. The lowermost fluid contains sugar of milk and some curd; the uppermost

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* Clarke, *Irish Trans.* ii. 175. † Parmentier, *Jour. de Phys.* xxxviii. 419.

does not differ from cream except in consistence. The oily part of the cream, then, cannot be separated by agitation from the curd*. This cream contains a greater portion of curd than the cream of cow's milk †.

When this milk, after the curd is separated from it, is slowly evaporated, it yields crystals of sugar of milk and of muriat of soda. The quantity of sugar is rather greater than in cow's milk. According to Haller, the sugar obtained from cow's milk is to that obtained from an equal quantity of woman's milk as 35 : 58, and sometimes as 37 : 67, and in all the intermediate ratios.

Its peculiarities.

Thus it appears that woman's milk differs from that of cow's in three particulars:

1. It contains a much smaller quantity of curd.
2. Its oil is so intimately combined with its curd, that it does not yield butter.
3. It contains rather more sugar of milk.

Parmentier and Deyeux ascertained, that the quantity of curd in woman's milk increases in proportion to the time after delivery ‡. Nearly the same thing has been observed with respect to cow's milk.

Ass's milk.

Ass's MILK has a very strong resemblance to human milk: it has nearly the same colour, smell, and consistence. When left at rest for a sufficient time, a cream forms upon its surface, but by no means in such abundance as in woman's milk. This cream, by very long agitation, yields a butter, which is always soft, white, and tasteless; and, what is singular, very readily mixes again with the butter-milk; but it may be again separated by agitation, while the vessel, which contains it, is plunged in cold water. Creamed ass's milk is thin,

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* Parmentier, *Jour. de Phys.* xxxviii. 419.

† Ibid.

‡ Ibid. 420.

and has an agreeable sweetish taste. Alcohol and acids separate from it a little curd, which has but a small degree of consistence. The serum yields sugar of milk and muriat of lime*.

Its peculiarities.

Ass's milk therefore differs from cow's milk in three particulars:

1. Its cream is less abundant and more insipid.

2. It contains less curd.

3. It contains more sugar of milk: the proportion is 35 : 80.

Goat's milk.

GOAT'S MILK, if we except its consistence, which is greater, does not differ much from cow's milk. Like that milk, it throws up abundance of cream, from which butter is easily obtained. The creamed milk coagulates just as cow's milk, and yields a greater quantity of curd. Its whey contains sugar of milk, muriat of lime, and muriat of soda †.

Ewe's milk.

EWE'S MILK resembles almost precisely that of the cow. Its cream is rather more abundant, and yields a butter which never acquires the consistence of butter from cow's milk. Its curd has a fat and viscid appearance, and is not without difficulty made to assume the consistence of the curd of cow's milk. It makes excellent cheese ‡.

Mare's milk.

MARE'S MILK is thinner than that of the cow, but scarcely so thin as human milk. Its cream cannot be converted into butter by agitation. The creamed milk coagulates precisely as cow's milk, but the curd is not so abundant. The serum contains sugar of milk, sulphat of lime, and muriat of lime §.

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* Parmentier, *Jour. de Phys.* xxxviii. 423.

† Ibid. 425.

‡ Ibid. 428.

§ Ibid. 431.

SECT. IX.

OF SALIVA.

The fluid secreted in the mouth, which flows in considerable quantity during a repast, is known by the name of *saliva*. All the properties of this liquor which had been observed by philosophers before the middle of the 18th century have been collected by Haller[*]: But since that time several additional facts have been related by Fourcroy, Du Tennetar, and Brugnatelli; and a very numerous set of experiments have been published by Mr Siebold in 1797, in his Treatise on the *Salivary System*.

Properties.

Saliva is a limpid fluid-like water; but much more viscid: it has neither smell nor taste. Its specific gravity, according to Hamberger, is 1.0167[†]; according to Siebold, 1.080. When agitated, it frothes like all other adhesive liquids; indeed it is usually mixed with air, and has the appearance of froth.

Absorbs oxygen.

It neither mixes readily with water nor oil[‡]; but by trituration in a mortar it may be so mixed with water as to pass through a filter[§]. It has a great affinity for oxygen, absorbs it readily from the air, and gives it out again to other bodies[‖]. Hence the reason why gold or silver, triturated with saliva in a mortar, is

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[*] Haller's *Physiol.* vol. vi.

[†] Ibid. p. 52.

[‡] Narcessus, Ibid. p. 54.

[§] Fordice on *Digest.* p. 51.

[‖] Fourcroy, *Ann. de Chim.* xxviii. 262.

oxidated, as Du Tennetar has observed; and why the killing of mercury by oils is much facilitated by spitting into the mixture*. Hence also, in all probability, the reason that saliva is a useful application to sores of the skin. Dogs, and several other animals, have constantly recourse to this remedy, and with much advantage.

Action of heat.

When boiled in water, a few flakes of albumen precipitate. When evaporated, it swells exceedingly, and leaves behind it a thin brown-coloured crust: But if the evaporation be conducted slowly, small cubic crystals of muriat of soda are formed; and when the evaporation is completed, there remains behind a substance which resembles vegetable gluten, and which takes fire on burning coals, exhaling the odour of prussic acid and of burning feathers. The viscidity of saliva, the property which it has of absorbing oxygen, and of being inspissated, and this glutinous residuum, announce the presence of animal mucilage as a component part.

When saliva is distilled in a retort, it frothes very much: 100 parts yield 80 parts of water nearly pure, then a little carbonat of ammonia, some oil, and an acid, which perhaps is the prussic. The residuum amounts to about 1.56 parts, and is composed of muriat of soda, phosphat of soda, and phosphat of lime†.

Action of air.

When saliva is left exposed to the air, it absorbs a considerable portion of it, a slight pellicle appears on its surface, it becomes muddy, and deposites some flakes,

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* Fourcroy, *Ann. de Chim.* xxviii. 262.

† Vorbeyen, Textor, Nuck, &c. as quoted by Haller, *Physiol.* vi. 55.—Fourcroy, ix. 365.

exhaling at the same time a strong ammoniacal odour. Soon after it putrefies, and becomes exceedingly fetid.

The acids and alcohol inspissate saliva; the alkalies disengage ammonia; oxalic acid precipitates lime; and the nitrats of lead, mercury, and silver, precipitate phosphoric and muriatic acids.

Its composition.

From these facts, it follows that saliva, besides water, which constitutes at least four-fifths of its bulk, contains the following ingredients:

1. Mucilage,
2. Albumen,
3. Muriat of soda,
4. Phosphat of soda,
5. Phosphat of lime,
6. Phosphat of ammonia.

But it cannot be doubted that, like all the other animal fluids, it is liable to many changes from disease, &c. Brugnatelli found the saliva of a patient labouring under an obstinate venereal disease impregnated with oxalic acid.

Salivary concretions and tartar.

The concretions which sometimes form in the salivary ducts, &c. and the tartar or bony crust which so often attaches itself to the teeth, are composed of phosphat of lime[*].

Pancreatic juice.

The PANCREATIC JUICE has never been examined with much attention; but it does not appear, from the experiments that have been made, to differ much from saliva.

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[*] Fourcroy, ix. 367.

SECT. X.

OF BILE.

Bile is a liquid of a yellowish green colour, an unctuous feel, bitter taste, and peculiar smell, which is secreted by the liver; and in most animals considerable quantities of it are usually found collected in the gall bladder.

History. Great attention has been paid to this liquid by physicians; because the ancients were accustomed to ascribe a very great number of diseases, and even affections of the mind, to its agency. The most accurate chemical analyses of it which have hitherto appeared are those of Mr Cadet, which were published in the Memoirs of the French Academy of Sciences for the year 1767, and of Van Bochaute, published in 1778. Several important observations had been previously made on it by Boyle, Boerhaave, Verheyn, Ramsay, and Baglivi; and some facts have since been added to our chemical knowledge of bile by Maclurg and Fourcroy. The experiments have chiefly been confined to the bile of oxen, known in this country by the name of *gall;* because it is most easily procured in large quantities.

Properties. The specific gravity of bile seems to vary, like that of all other animal fluids. According to Hartmann, it is 1.027 *. When strongly agitated, it lathers like soap; and for this reason, as well as from a medical

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* Haller's *Phys.* vi. 546.

theory concerning its use, it has been often called an *animal soap*.

It mixes readily with water in any proportion, and assumes a yellow colour; but it refuses to unite with oil; when the two fluids are agitated together, the instant that they are left at rest the oil separates and swims on the surface *. Bile, however, dissolves a portion of soap readily, and is often employed to free cloth from greasy spots.

Contains albumen,

When muriatic acid is poured upon bile, let it be ever so fresh, an odour of sulphurated hydrogen gas is constantly exhaled †. When on 100 parts of ox-bile four parts of strong muriatic acid are poured, the whole instantly coagulates; but in some hours the greater part becomes again fluid: and when passed through the filter it leaves 0.26 of a white matter, which has all the properties of albumen ‡. This matter was detected by Ramsay, who found that it could be precipitated from bile by alcohol, acetous acid, sulphat of potass, and muriat of soda §. Cadet ascertained, that 100 parts of ox-bile contain about 0.52 of albumen. It is precipitated in a state of purity by oxy-muriatic acid, provided that acid be not employed in excess ||.

A resin,

The muriatic acid solution, after the separation of the albumen, has a fine grass-green colour. When concentrated by some hours evaporation in a glass cucurbit on hot coals, it deposites a very copious precipitate, and loses almost the whole of its green colour. By

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* Ramsay, *Thesaur. Med. Edin.* ii. 459.—Maclurg, p. 10.

† Cadet, *Mem. Par.* 1767, p. 340.

‡ Ibid.

§ *Thesaur. Edin.* ii. 460.

|| Fourcroy, *Ann. de Chim.* vii. 176.

longer evaporation, a new precipitate, similar to the first, appears, and the remaining liquid assumes the colour of beer. This precipitate possesses all the properties of the *resin of bile*. In its moist state it amounts to 10.8 parts *. The same substances may be obtained from bile by nitric acid; but the resin in that case has a yellow colour, and its properties are somewhat altered †.

Soda,

If 100 parts of bile be gently evaporated to dryness by a very moderate heat, the dry mass only weighs 10 parts, and has a brownish black colour. When exposed to a strong heat in a crucible, this matter swells up, takes fire, and emits very thick fumes. The residuum amounts to 1.09. By lixiviation with water, 1.87 of crystallized soda may be obtained ‡; consequently 100 parts of bile contain, according to Mr Kirwan's table, 0.403546 of pure soda. But it is evident that, by this method, part of the soda must have been evaporated; therefore 100 parts of bile contain more than 0.403546 of soda. Besides the soda, there is found also a small portion of muriat of soda § and phosphat of soda ||.

And salts.

Cadet found the residuum, after the separation of the salts, of a black colour; it gave some traces of iron. He also obtained a calcareous salt from bile, which he considered as a sulphat; but it has been ascertained since to be phosphat of lime.

Cadet also obtained from bile, by evaporating the muriatic acid solution after the separation of the resin, a salt which crystallized in trapeziums; it had a sweet-

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* Cadet, *Mem. Par.* 1767. p. 340.

† Ibid. p. 343.

‡ Ibid. p. 350.

§ Ibid.

|| Fourcroy, x. 41.

ish taste, and was considered by him as analogous to sugar of milk [*].

Composition.

Thus we see that bile contains the following ingredients:

1. Water,
2. Resin,
3. Albumen,
4. Soda,
5. Sulphurated hydrogen,
6. A sweetish salt,
7. Muriat of soda,
8. Phosphat of lime,
9. Phosphat of soda,
10. Iron.

The proportion of these ingredients has by no means been ascertained. The presence of iron has been denied in bile, because it gives no blue precipitate with prussic alkali, and because tincture of nutgalls does not give it a black colour [†]. But these reasons are insufficient to overturn the experiment of Cadet, who actually found it in bile.

When four parts of vinegar and five of bile are mixed together, the mixture has a sweet taste, and does not coagulate milk. The lactic acid has precisely the same effect as vinegar [‡].

Distillation of bile.

When bile is distilled in a water-bath, it affords a transparent watery liquor, which contracts a pretty strong odour, not unlike that of musk or amber, especially if the bile has been kept for some days before it is submitted to distillation [§]. The residuum is of a deep brownish green; it attracts moisture from the air, and dissolves readily in water. When distilled in a retort, it affords a watery liquor of a yellowish colour, a fetid odour, and impregnated with carbonat and zoonat of ammonia. To this liquid an oil succeeds, at first light

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[*] Cadet, *Mem. Par.* 1767, p. 342.

[†] Maclurg, p. 56.

[‡] Ramsay, *Thesaur. Med. Edin.* ii. 462.

[§] Fourcroy, x. 21.

and liquid, then thick and empyreumatic, and insupportably fetid. Some carbonat of ammonia attaches itself to the sides of the receiver; and carbonated hydrogen gas, carbonic acid gas, mixed with sulphurated hydrogen gas, are exhaled in abundance. The coal which remains is black, bulky, and spongy, and easily incinerated *. Bile, exposed to a temperature between 65° and 85°, soon loses its colour and viscidity, acquires a nauseous smell, and deposites whitish mucilaginous flakes. After the putrefaction has made considerable progress, its smell becomes sweet, and resembles amber. If bile be heated, and slightly concentrated by evaporation, it may be kept for many months without alteration †.

SECT. XI.

OF BILIARY CALCULI.

History.

Hard bodies sometimes form in the gall-bladder, or in the duct through which the bile passes into the intestinal canal, and stop up the passage altogether. These concretions have got the name of *biliary calculi* or *gall-stones*. As they are formed in the midst of bile, and as the substances of which they are composed must be derived from the bile, it is proper to give an account of them here, because their properties cannot fail to throw some additional light on the nature of bile itself.

These concretions naturally drew the attention of

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* Fourcroy, x. 22.

† Vauquelin.

physicians, because they soon ascertained that they occasioned the disease called *jaundice*. Accordingly they were examined and described by different chemists; and the facts ascertained before 1764 were collected by Haller in the sixth volume of his Physiology. Since that period, a Treatise has been published on them by Vicq d'Azyr, and several new facts have been discovered by Poulletier de la Sale, Fourcroy, Gren, and Saunders.

Divisible into four classes.

Such of the biliary calculi as have been hitherto examined with attention, may be arranged under four classes.

1. The first kind comprehends those which have a white colour, and a crystallized, shining, lamellated structure.

2. The second is brown coloured, and has the appearance of inspissated bile.

3. The third class comprehends those calculi which are composed of a mixture of the substances which constitute the two last.

4. The fourth comprehends those gall stones which do not flame, but gradually waste away at a red heat.

Let us take a view of each of these classes of biliary calculi.

1. Resembles spermaceti.

1. The first species of biliary calculi was pointed out for the first time by Haller in a Dissertation published in 1749. Walther afterwards added several new facts; and at last it was accurately described by Vicq d'Azyr. It is almost always of an oval shape, sometimes as large as a pigeon's egg, but commonly about the size of a sparrow's; and for the most part only one calculus (when of this species) is found in the gall-bladder at a time. It has a white colour; and when

Chap II.

roken, presents crystalline plates or striæ, brilliant and hite like mica, and having a soft greasy feel. Some-mes its colour is yellow or greenish; and it has con-antly a nucleus of inspissated bile [*].

Its specific gravity is inferior to that of water: Gren ound the specific gravity of one 0.803[†].

When exposed to a heat considerably greater than at of boiling water, this crystallized calculus softens nd melts, and crystallizes again when the temperature lowered[‡]. It is altogether insoluble in water; but ot alcohol dissolves it with facility. Alcohol, of the mperature of 167°, dissolves $\frac{1}{20}$ of its weight of this ubstance; but alcohol, at the temperature of 60°, carcely dissolves any of it[§]. As the alcohol cools, e matter is deposited in brilliant plates resembling lc or boracic acid[||]. It is soluble in oil of turpen-ne[¶]. When melted, it has the appearance of oil, nd exhales the odour of melted wax: when suddenly eated, it evaporates altogether in a thick smoke. It soluble in pure alkalies, and the solution has all the roperties of a soap. Nitric acid also dissolves it; but is precipitated unaltered by water[**].

This matter, which is evidently the same with the rystals which Cadet obtained from bile, and which he onsidered as analogous to sugar of milk, has a strong esemblance to spermaceti. Like that substance, it is f an oily nature, and inflammable; but it differs from t in a variety of particulars.

Since it is contained in bile, it is not difficult to see

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[*] Fourcroy, *Ann. de Chim.* iii. 249.

[†] *Ann. de Chim.* v. 186.

[‡] Fourcroy, Ibid. ii. 123.

[§] Ibid. p. 180.

[||] Ibid. iii. 256.

[¶] Gren, Ibid. v. 187.

[**] Fourcroy, Ibid. iii. 247.

how it may crystallize in the gall-bladder if it happens to be more abundant than usual; and the consequence must be a gall-stone of this species. Fourcroy found a quantity of the same substance in the dried human liver*.

2d Species inspissated bile.

2. The second species of biliary calculus is of a round or polygonal shape, often of a grey colour externally, and brown within. It is formed of concentric layers of a matter which seems to be inspissated bile; and there is usually a nucleus of the white crystalline matter at the centre. For the most part there are many of this species of calculus in the gall-bladder together: indeed it is frequently filled with them. The calculi belonging to this species are often light and friable, and of a brownish-red colour. The gall-stones of oxen used by painters belong to this species.

3d Species a mixture of the two first.

3. The third species of calculi are most numerous of all. Their colour is often deep brown or green; and when broken, a number of spermaceti crystals are observable mixed with the inspissated bile†.

The calculi belonging to these three species are soluble in alkalies, in soap leys, in alcohol, and in oils.

4th Species insoluble in alcohol.

4. Concerning the fourth species of gall-stone, very little is known with accuracy. Dr Saunders tells us, that he has met with some gall-stones insoluble both in alcohol and oil of turpentine; some which do not flame, but become red, and consume to an ash like a charcoal‡. Haller quotes several examples of similar calculi§.

Gall-stones often occur in the inferior animals, particularly in cows and hogs; but the biliary concretions

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[*] Fourcroy, *Ann. de Chim.* iii. 126.

[†] Fourcroy, x. 59.

[‡] *On the Liver*, p. 112.

[§] *Physiol.* vi. 567.

these animals have not hitherto been examined with ch attention.

SECT. XII.

OF THE CERUMEN OF THE EAR.

RUMEN is a viscid yellow-coloured liquid secreted the glands of the auditory canal, which gradually be- nes concrete by exposure to the air. For all the s respecting its composition at present known, we indebted to Fourcroy and Vauquelin, especially the , who analysed a considerable portion of it.

Properties.

t has an orange-yellow colour and a bitter taste. en slightly heated upon paper, it melts, and stains paper like an oil; at the same time it emits a slight- romatic odour. On burning coals it softens, emits hite smoke, which resembles that given out by burn- fat; it afterwards melts, swells, becomes dark-co- ed, and emits an ammoniacal and empyreumatic ur. A light coal remains behind.

Vhen agitated in water, cerumen forms a kind of lsion, which soon putrefies, depositing at the same white flakes.

Contains albumen,

lcohol, when assisted by heat, dissolves $\frac{5}{8}$ of the ce- en; the $\frac{3}{8}$ which remain behind have the proper- of albumen, mixed however with a little oily mat-

And a resin.

When the alcohol is evaporated, it leaves a deep ge residuum of a very bitter taste, having a smell a consistence analagous to turpentine. It melts n heated, evaporates in a white smoke without lea- any residuum, and in short resembles very strongly the *resin of bile*. Ether also dissolves this oily body; but it is much less bitter and much lighter coloured. When the albuminous part of cerumen is burnt, it leaves traces of soda and of phosphat of lime. From these facts Vauquelin considers cerumen as composed of the following substances:

Composition.

1. Albumen,
2. An inspissated oil,
3. A colouring matter,
4. Soda,
5. Phosphat of lime.

The presence of the colouring matter is inferred from the portion taken up by ether being less coloured than that taken up by alcohol [*].

SECT. XIII.

OF TEARS AND MUCUS.

1. THAT peculiar fluid which is employed in lubricating the eye, and which is emitted in considerable quantities when we express grief by weeping, is known by the name of *tears*. For an accurate analysis of this fluid, we are indebted to Messrs Fourcroy and Vauquelin. Before their dissertation, which was published in 1791, appeared, scarcely any thing was known about the nature of tears.

Properties.

The liquid called tears is transparent and colourless like water; it has scarcely any smell, but its taste is always perceptibly salt. Its specific gravity is somewhat greater than that of distilled water. It gives to paper, stained with the juice of the petals of mallows or violet, a permanently green colour, and therefore contains a

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[*] Fourcroy, ix. 373.

xed alkali [*]. It unites with water, whether cold or ot, in all proportions. Alkalies unite with it readily, nd render it more fluid. The mineral acids produce o apparent change upon it [†]. Exposed to the air, is liquid gradually evaporates, and becomes thicker. Vhen nearly reduced to a state of dryness, a number f cubic crystals form in the midst of a kind of muci- ge. These crystals possess the properties of muriat of da; but they tinge vegetable blues green, and there- re contain an excess of soda. The mucilaginous mat- r acquires a yellowish colour as it dries [‡].

This liquid boils like water, excepting that a consi- erable froth collects on its surface. If it be kept a fficient time at the boiling temperature, $\frac{96}{100}$ parts of evaporate in water; and there remain about .04 parts f a yellowish matter, which by distillation in a strong eat yields water and a little oil: the residuum consists f different saline matters [§].

When alcohol is poured into this liquid, a mucilagi- ous matter is precipitated in the form of large white kes. The alcohol leaves behind it, when evaporated, aces of muriat of soda and soda. The residuum which mains behind, when inspissated tears are burnt in the en air, exhibits some traces of phosphat of lime and osphat of soda [‖].

Composition.

Thus it appears that tears are composed of the fol- wing ingredients:

1. Water,
2. Mucilage,
3. Muriat of soda,
4. Soda,
5. Phosphat of lime,
6. Phosphat of soda.

Fourcroy and Vauquelin, *Jour. de Phys.* xxxix. 256.

[†] Ibid. p. 257.

Ibid. p. 256.

[§] Ibid.

[‖] Ibid. p. 259.

The saline parts amount only to about 0.01 of the whole, or probably not so much.

Of the mucilaginous part.

The *mucilage* contained in the tears has the property of absorbing oxygen gradually from the atmosphere, and of becoming thick and viscid, and of a yellow colour. It is then insoluble in water, and remains long suspended in it without alteration. When a sufficient quantity of oxy-muriatic acid is poured into tears, a yellow flaky precipitate appears absolutely similar to this inspissated mucilage. The oxy-muriatic acid loses its peculiar odour; hence it is evident that it has given out oxygen to the mucilage. The property which this mucilage has of absorbing oxygen, and of acquiring new qualities, explains the changes which take place in tears which are exposed for a long time to the action of the atmosphere, as is the case in those persons who labour under a fistula lachrymalis *.

Mucus of the nose.

2. The MUCUS of the nose has also been examined by Fourcroy and Vauquelin. They found it composed of precisely the same ingredients with the tears. As this fluid is more exposed to the action of the air than the tears, in most cases its mucilage has undergone less or more of that change which is the consequence of the absorption of oxygen. Hence the reason of the greater viscidity and consistence of the mucus of the nose; hence also the great consistence which it acquires during colds, where the action of the atmosphere is assisted by the increased action of the parts †.

Mucus of cavities.

3. As to the MUCUS, which lubricates the alimentary canal, the trachea, the bronchiæ, the urethra, and all the different cavities of the body, nobody has hitherto subjected it to analysis, because it cannot be obtained

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* Fourcroy and Vauquelin, *Jour. de Phys.* xxxix. 257.

† Ibid. 259.

n sufficient quantity. It is viscid, and no doubt conains a mucilaginous substance, similar to that contained n the saliva, the tears, and the mucus of the nose; as, ike these liquids, it is liable to become much more thick y exposure to the air.

Humours of the eye.

4. Neither have the different HUMOURS of the eye, he aqueous, vitreous, and crystalline, been subjected to nalysis; nor can the accuracy of the observations made n them by the earlier physicians be depended on.

SECT. XIV.

OF SINOVIA.

WITHIN the capsular ligament of the different joints f the body there is contained a peculiar liquid, inended evidently to lubricate the parts, and to facilitate heir motion. This liquid is known among anatomists y the name of *sinovia*.

Whether it be the same in different animals, or even n all the different joints of the same animal, has not een determined; as no accurate analysis of the sinovia f different animals has been attempted. The only anaysis of sinovia which has hitherto appeared is that by Mr Margueron, which was published in the 14th voume of the *Annales de Chimie*. He made use of sinoia obtained from the joints of the lower extremities of xen.

Sinovia of the ox.

The sinovia of the ox, when it has just flowed from he joint, is a viscid semitransparent fluid, of a greenish white colour, and a smell not unlike frog spawn. It very soon acquires the consistence of jelly; and this happens equally whether it be kept in a cold or a hot temperature, whether it be exposed to the air or excluded from it. This consistence does not continue long; the sinovia soon recovers again its fluidity, and at the same time deposites a thready-like matter *.

Sinovia mixes readily with water, and imparts to that liquid a great deal of viscidity. The mixture frothes when agitated; becomes milky when boiled, and deposites some pellicles on the sides of the dish; but its viscidity is not diminished †.

Contains albumen,

When alcohol is poured into sinovia, a white substance precipitates, which has all the properties of albumen. One hundred parts of sinovia contain 4.52 of albumen. The liquid still continues as viscid as ever; but if acetous acid be poured into it, the viscidity disappears altogether, the liquid becomes transparent, and deposites a quantity of matter in white threads, which possesses the following properties: 1. It has the colour, smell, taste, and elasticity of vegetable gluten. 2. It is soluble in concentrated acids and pure alkalies. 3. It is soluble in cold water, the solution frothes; acids and alcohol precipitate the fibrous matter in flakes. One hundred parts of sinovia contain 11.86 of this matter ‡.

And a fibrous matter,

When the liquid, after these substances have been separated from it, is concentrated by evaporation, it deposites crystals of acetite of soda. Sinovia, therefore, contains *soda*. Margueron found that 100 parts of sinovia contained about 0.71 of soda.

When strong sulphuric, muriatic, nitric, acetic, or sulphurous acid is poured into sinovia, a number of

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* Margueron, *Ann. de Chim.* xiv. 124.

† Ibid. p. 126.

‡ Ibid. p. 126—130.

white flakes precipitate at first; but they are soon redissolved; and the viscidity of the liquid continues. When these acids are diluted with five times their weight of water, they diminish the transparency of sinovia, but not its viscidity; but when they are so much diluted that their acid taste is just perceptible, they precipitate the peculiar thready matter, and the viscidity of the sinovia disappears *.

And salts.

When sinovia is exposed to a dry atmosphere it gradually evaporates, and a scaly residuum remains, in which cubic crystals, and a white saline efflorescence, are apparent. The cubic crystals are muriat of soda. One hundred parts of sinovia contain about 1.75 of this salt. The saline efflorescence is carbonat of soda †.

Sinovia soon putrefies in a moist atmosphere, and during the putrefaction ammonia is exhaled. When it is distilled in a retort, there come over, first water, which soon putrefies; then water containing ammonia; then empyreumatic oil and carbonat of ammonia. From the residuum muriat and carbonat of soda may be extracted by lixiviation. The coal contains some phosphat of lime ‡.

Composition.

From the analysis of Mr Margueron it appears that sinovia is composed of the following ingredients:

11.86	fibrous matter
4.52	albumen
1.75	muriat of soda
.71	soda
.70	phosphat of lime ‖
80.57	water
100.00	

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* Margueron, *Ann. de Chim.* xiv. 127. † Ibid. 125. ‡ Ibid. 128.

‖ Mr Hatchett found only 0.208 of phosphat of lime in the sinovia

How far the sinovia of the human body resembles that of oxen it is impossible to say. The following fact renders it probable, that it either contains different ingredients, or is liable to alteration from disease. Concretions often form in the joints of gouty people, and make their way through the skin. These, in common language, are called *chalk stones*. Dr Pearson and Mr Tennant analysed some of them, and found them composed of *urat of soda* *. This analysis has been repeated by Fourcroy and confirmed †. It is doubtless this fact that has induced Fourcroy to conjecture, that uric acid forms a constituent part of sinovia ‡.

Gouty concretions.

SECT. XV.

OF SEMEN.

The peculiar liquid secreted in the testes of males, and destined for the impregnation of females, is known by the name of *semen*. The human semen alone has hitherto been subjected to chemical analysis. Nothing is known concerning the seminal fluid of other animals. Vauquelin published an analysis of the human semen in 1791.

Properties.

Semen, when newly ejected, is evidently a mixture of two different substances: the one, fluid and milky, which is supposed to be secreted by the prostate gland;

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which he examined. He found, however, traces of some other phosphat; probably phosphat of soda. *Phil. Trans.* 1799, p. 246.

* *Jour. de Phys.* xlv. 399. † Fourcroy, x. 267. ‡ Ibid. ix. 224.

Chap. II.

the other, which is considered as the true secretion of the testes, is a thick mucilaginous substance, in which numerous white shining filaments may be discovered*. It has a slight disagreeable odour, an acrid irritating taste, and its specific gravity is greater than that of water. When rubbed in a mortar it becomes frothy, and of the consistence of pomatum, in consequence of its enveloping a great number of air-bubbles. It converts paper stained with the blossoms of mallows or violets to a green colour, and consequently contains an alkali†.

As the liquid cools, the mucilaginous part becomes transparent, and acquires greater consistency; but in about twenty minutes after its emission, the whole becomes perfectly liquid. This liquefaction is not owing to the absorption of moisture from the air, for it loses instead of acquiring weight during its exposure to the atmosphere; nor is it owing to the action of the air, for it takes place equally in close vessels ‡.

Semen is insoluble in water before this spontaneous liquefaction, but afterwards it dissolves readily in it. When alcohol or oxy-muriatic acid is poured into this solution, a number of white flakes are precipitated§. Concentrated alkalies facilitate its combination with water. Acids readily dissolve the semen, and the solution is not decomposed by alkalies; neither indeed is the alkaline solution decomposed by acids||.

Lime disengages no ammonia from fresh semen; but after that fluid has remained for some time in a moist and warm atmosphere, lime separates a great quantity

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* Vauquelin, *Ann. de Chim.* ix. 64.

† Ibid. p. 65.

‡ Ibid. p. 66.

§ Ibid. p. 70.

|| Ibid. p. 71.

from it. Consequently ammonia is formed during the exposure of semen to the air[*].

Contains mucilage,

When oxy-muriatic acid is poured into semen, a number of white flakes precipitate, and the acid loses its peculiar odour. These flakes are insoluble in water, and even in acids. If the quantity of acid be sufficient, the semen acquires a yellow colour. Thus it appears that semen contains a mucilaginous substance analogous to that of the tears, which coagulates by absorbing oxygen. Mr Vauquelin obtained from 100 parts of semen six parts of this mucilage.

Phosphat of lime,

When semen is exposed to the air about the temperature of 60°, it becomes gradually covered with a transparent pellicle, and in three or four days deposites small transparent crystals, often crossing each other in such a manner as to represent the spokes of a wheel. These crystals, when viewed through a microscope, appear to be four-sided prisms, terminated by very long four-sided pyramids. They may be separated by diluting the liquid with water, and decanting it off. They have all the properties of phosphat of lime[†]. If, after the appearance of these crystals, the semen be still allowed to remain exposed to the atmosphere, the pellicle on its surface gradually thickens, and a number of white round bodies appear on different parts of it. These bodies also are phosphat of lime, prevented from crystallizing regularly by the too rapid abstraction of moisture. Mr Vauquelin found that 100 parts of semen contain three parts of phosphat of lime[‡]. If at this period of the evaporation the air becomes moist, other crystals appear in the semen, which have the pro-

And soda.

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[*] *Ann. de Chim.* ix. 71.

[†] Ibid. p. 67. and 73.

[‡] Ibid. p. 68.

perties of carbonat of soda. The evaporation does not go on to complete exsiccation, unless at the temperature of 77°, and when the air is very dry. When all the moisture is evaporated, the semen has lost 0 9 of its weight, the residuum is semi-transparent like horn, and brittle *.

When semen is kept in very moist air, at the temperature of about 77°, it acquires a yellow colour, like that of the yolk of an egg; its taste becomes acid, it exhales the odour of putrid fish, and its surface is covered with abundance of the byssus septica †.

Action of heat.

When dried semen is exposed to heat in a crucible, it melts, acquires a brown colour, and exhales a yellow fume, having the odour of burnt horn. When the heat is raised, the matter swells, becomes black, and gives out a strong odour of ammonia. When the odour of ammonia disappears, if the matter be lixiviated with water, an alkaline solution may be obtained, which, by evaporation, yields crystals of carbonat of soda. Mr Vauquelin found that 100 parts of semen contain one part of soda ‡. If the residuum be incinerated, there will remain only a quantity of white ashes, consisting of phosphat of lime.

Composition.

Thus it appears that semen is composed of the following ingredients:

90 water
6 mucilage
3 phosphat of lime
1 soda

100

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* *Ann. de Chim.* ix. 68.

† Ibid.

‡ Ibid. p. 75.

SECT. XVI.

OF THE LIQUOR OF THE AMNIOS

The fœtus in the uterus is enveloped in a peculiar membranous covering, to which anatomists have given the name of *amnios*. Within this amnios there is a liquid, distinguished by the name of the *liquor of the amnios*, which surrounds the fœtus on every part. This liquid, as might have been expected, is very different in different animals, at least the liquor amnii in women and in cows, which alone have hitherto been analysed, have not the smallest resemblance to each other. These two liquids have been lately analysed by Vauquelin and Buniva, and the result of their analysis has been published in the 33d volume of the *Annales de Chimie*.

Liquor of the human amnios.

1. The liquor of the amnios of women is a fluid of a slightly milky colour, a weak but pleasant odour, and a saltish taste. The white colour is owing to a curdy matter suspended in it, for it may be obtained quite transparent by filtration*.

Its specific gravity is 1.005. It gives a green colour to the tincture of violets, and yet it reddens very decidedly the tincture of turnsole. These two properties would indicate at once the presence of an acid and of an alkali. It frothes considerably when agitated. On the application of heat it becomes opaque, and has then a great resemblance to milk diluted with a large

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* *Ann. de Chim.* xxxiii. 270.

quantity of water. At the same time it exhales the odour of boiled white of egg [*].

Acids render it more transparent. Alkalies precipitate an animal matter in small flakes. Alcohol likewise produces a flaky precipitate, which, when collected and dried, becomes transparent, and very like glue. The infusion of nutgalls produces a very copious brown coloured precipitate. Nitrat of silver occasions a white precipitate, which is insoluble in nitric acid, and consequently is muriat of silver [†].

When slowly evaporated it becomes slightly milky, a transparent pellicle forms on its surface, and it leaves a residuum which does not exceed 0.012 of the whole. By lixiviating this residuum, and evaporating the ley, crystals of muriat and carbonat of soda may be obtained. The remainder, when incinerated, exhales a fetid and ammoniacal odour, resembling that of burning horn; the ashes consist of a small quantity of carbonat of soda, and of phosphat and carbonat of lime [‡].

Composition.

Thus we see that the liquor of the human amnios is composed of about

$$\begin{array}{rl} 98.8 & \text{water,} \\ 1.2 & \left\{\begin{array}{l}\text{albumen,}\\ \text{muriat of soda, soda,}\\ \text{phosphat of lime, lime.}\end{array}\right. \\ \hline 100.0 & \end{array}$$

Curdy matter deposited on the fœtus.

While the fœtus is in the uterus, a curdy-like matter is deposited on the surface of its skin, and in particular parts of its body. This matter is often found collected in considerable quantities. It is evidently deposited from the liquor of the amnios; and consequently the

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[*] *Ann. de Chim.* xxxiii. 271.

[†] Ibid.

[‡] Ibid. 272.

knowledge of its peculiar nature must throw considerable light upon the properties and use of that liquor. For an analysis of this substance we are also indebted to Vauquelin and Buniva.

Its colour is white and brilliant; it has a soft feel, and very much resembles newly prepared soap. It is insoluble in water, alcohol, and oils. Pure alkalies dissolve part of it, and form with it a kind of soap. On burning coals it decrepitates like a salt, becomes dry and black, exhales vapours which have the odour of empyreumatic oil, and leaves a residuum which is very difficultly reduced to ashes. When heated in a platinum crucible it decrepitates, lets an oil exsude, curls up like horn, and leaves a residuum, consisting chiefly of carbonat of lime *.

These properties shew that this matter is different from every one of the component parts of the liquor of the amnios, and that it has a great resemblance to the *fat*. It is probable, as Vauquelin and Buniva have conjectured, that it is formed from the albumen of that liquid, which has undergone some unknown changes. It has been long known, that the parts of a fœtus, which has lain for some time after it has been deprived of life in the uterus, are sometimes converted into a kind of fatty matter. It is evident that this substance, after it is deposited upon the skin of the fœtus, must preserve it in a great measure from being acted upon by the liquor of the amnios.

Liquor of the amnios of the cow.

2. The liquor of the amnios of the cow has a viscidity similar to mucilage of gum arabic, a brownish red colour, an acid and bitter taste, and a peculiar odour,

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* *Ann. de Chim.* xxxiii. 274.

not unlike that of some vegetable extracts. Its specific gravity is 1.028. It reddens the tincture of turnsole, and therefore contains an acid. Muriat of barytes causes a very abundant precipitate, which renders it probable that it contains sulphuric acid. Alcohol separates from it a great quantity of a reddish coloured matter *.

When this liquid is evaporated, a thick frothy scum gathers on the surface, which is easily separated, and in which some white acid-tasted crystals may be discovered. By continuing the evaporation, the matter becomes thick and viscid, and has very much the look of honey. Alcohol boiled upon this thick matter, and filtered off, deposites upon cooling brilliant needle-formed crystals nearly an inch in length. These crystals may be obtained in abundance by evaporating the liquor of the amnios to a fourth part of its bulk, and then allowing it to cool. The crystals soon make their appearance. They may be separated and purified by washing them in a small quantity of cold water. These crystals are *amniotic* acid †.

If after the separation of this acid the liquor of the amnios be evaporated to the consistence of a syrup, large transparent crystals appear in it, which have all the properties of sulphat of soda. The liquid of the amnios of cows contains a considerable quantity of this salt.

Composition.

Thus it appears that the liquor of the amnios of cows contains the following ingredients:

1. Water,
2. A peculiar animal matter,
3. Acid,
4. Sulphat of soda.

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* *Ann. de Chim.* xxxiii. 275.

† Ibid. 276.

The animal matter possesses the following properties: It has a reddish brown colour, and a peculiar taste; it is very soluble in water, but insoluble in alcohol, which has the property of separating it from water. When exposed to a strong heat it swells, exhales first the odour of burning gum, then of empyreumatic oil and of ammonia, and at last the peculiar odour of prussic acid becomes very conspicuous. It differs from gelatine in the viscidity which it communicates to water, in not forming a jelly when concentrated, and in not being precipitated by tan. It must be therefore ranked among the very undefined and inaccurate class of *animal mucilages*. When burnt, it leaves a very large coal, which is readily incinerated, and leaves a little white ashes, composed of phosphat of magnesia, and a very small proportion of phosphat of lime [*].

SECT. XVII.

OF URINE.

No animal substance has attracted more attention than urine, both on account of its supposed connection with various diseases, and on account of the very singular products which have been obtained from it. Mr Boyle, and the other chemists who were his contemporaries, were induced to attend particularly to this liquid, by the discovery of a method of obtaining phosphorus from it.

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[*] *Ann. de Chim.* xxxiii. 278.

Boerhaave, Haller, Haupt, Margraf, Pott, Rouelle, Proust, and Klaproth, successively improved the method of obtaining the phosphoric salts from urine, or added something to our knowledge of the component parts of these salts. Scheele added greatly to our knowledge of urine by detecting several new substances in it which had not been suspected. Cruickshank has given us a very valuable paper on urine in the second edition of *Rollo's Diabetes ;* Fourcroy and Vauquelin have lately published a very complete analysis of it; and Mr Proust has published another, no less ingenious, in which he points out the existence of several substances which had been overlooked by other chemical philosophers.

Contains an acid,

1. Urine reddens paper stained with turnsole and with the juice of radishes, and therefore contains an acid.

Super-phosphat of lime,

2. If a solution of ammonia be poured into fresh urine, a white powder precipitates, which has the properties of phosphat of lime. The presence of this substance in urine was first discovered by Scheele [*]. If lime water be poured into urine, phosphat of lime precipitates in greater abundance than when ammonia is used ; consequently the acid which urine contains is the phosphoric. Thus we see that the phosphat of lime is kept dissolved in urine by an excess of acid, or it is in the state of super-phosphat. This also was first discovered by Scheele [†]. This substance is most abundant in the urine of the sick. Berthollet has observed, that the urine of gouty people is less acid than that of people in perfect health. The average quantity of phosphat

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[*] Scheele, i. 208.

[†] Ibid.

of lime in healthy urine is, as Cruickshank has ascertained, about $\frac{1}{900}$ of the weight of the urine [*].

Phosphat of magnesia,

3. If the phosphat of lime precipitated from urine be examined, a little magnesia will be found mixed with it. Fourcroy and Vauquelin have ascertained that this is owing to a little phosphat of magnesia which urine contains, and which is decomposed by the alkali or lime employed to precipitate the phosphat of lime [†].

Carbonic acid,

4. Proust informs us that carbonic acid exists in urine, and that its separation occasions the froth which appears during the evaporation of urine [‡]. Fourcroy and Vauquelin, on the other hand, consider this acid as formed during the evaporation by the decomposition of the urea.

Carbonat of lime,

5. Proust has observed, that urine kept in new casks deposites small crystals which effloresce in the air and fall to powder. These crystals possess the properties of carbonat of lime [§]. Hence we must conclude that urine contains carbonat of lime; a very extraordinary fact, if we reflect that super-phosphat of lime is also present.

Uric acid,

6. When fresh urine cools, it often lets fall a brick-coloured precipitate, which Scheele first ascertained to be crystals of uric acid. All urine contains this acid, even when no sensible precipitate appears when it cools. For if a sufficient quantity of clear and fresh urine be evaporated to $\frac{1}{178}$ of its weight, a subtle powder precipitates to the bottom, and attaches itself in part very firmly to the vessel. This part may be dissolved in

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[*] *Phil. Mag.* ii. 241.

[†] *Ann. de Chim.* xxxi. 66.

[‡] *Ann. de Chim.* xxxvi. 260.

[§] Ibid. p. 263.

pure alkali, and precipitated again by acetous acid. It exhibits all the properties of uric acid *.

Rosaceous acid,

7. During intermittent fevers urine deposites a very copious precipitate, which has been long known to physicians under the name of *lateritious sediment*. This sediment always makes its appearance at the crisis of fevers. In gouty people, the same sediment appears in equal abundance towards the end of a paroxysm of the disease. And if this sediment suddenly disappears after it has begun to be deposited, a fresh attack may be expected †. Scheele considered this sediment as uric acid mixed with some phosphat of lime; and the same opinion has been entertained by other chemists: but Proust affirms that it consists chiefly of a different substance, to which he has given the name of *rosaceous* acid from its colour; mixed with a certain proportion of uric acid and phosphat of lime. This rosaceous acid, he informs us, is distinguished from the uric by the facility with which it dissolves in hot water, the violet precipitate which it occasions in muriat of gold, and by the little tendency which it has to crystallize ‡.

Benzoic acid,

8. If fresh urine be evaporated to the consistence of a syrup, and muriatic acid be then poured into it, a precipitate appears which possesses the properties of benzoic acid. Scheele first discovered the presence of benzoic acid in urine. He evaporated it to dryness, separated the saline part, and applied heat to the residuum. The benzoic acid was sublimed, and found crystallized in the receiver. The above method was first proposed by Fourcroy and Vauquelin §. By it very considerable

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* Scheele, 207.

† Cruikshank, *Phil. Mag.* ii. 249.

‡ *Ann. de Chim.* xxxvi. 265.

§ Ibid. xxxi. 62.

quantities of benzoic acid may be obtained from the urine of horses and cows, where it is much more abundant than in human urine. In human urine it varies from $\frac{1}{1000}$ to $\frac{1}{10000}$ of the whole*. Proust affirms that the acid obtained by Scheele's process is not the benzoic, but another possessed of similar properties; but differing in this circumstance, that nitric acid decomposes it, whereas it only whitens benzoic acid †.

Albumen and gelatine,

9. When an infusion of tan is dropt into urine, a white precipitate appears, having the properties of the combination of tan and albumen, or gelatine. Urine, therefore, contains albumen or gelatine. These substances had been suspected to be in urine, but their presence was first demonstrated by Seguin, who discovered the above method of detecting them. Their quantity in healthy urine is very small. Cruikshank found that the precipitate afforded by tan in healthy urine amounted to $\frac{1}{240}$th part of the weight of the urine ‡. It is to these substances that the appearance of the *cloud*, as it is called, or the mucilaginous matter, which is sometimes deposited as the urine cools, is owing. It is probable that healthy urine contains only gelatine, and not albumen, though the quantity is too small to admit of accurate examination; but in many diseases the quantity of these matters is very much increased. The urine of dropsical people often contains so much albumen, that it coagulates not only on the addition of acids, but even on the application of heat §. In all cases of impaired digestion, the albuminous and gelatinous part of urine is much increased. This forms one

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* *Ann. de Chim.* xxxi. 63.

† Ibid xxxvi. p. 273.

‡ *Phil. Mag.* ii. 243.

§ Cruikshank, Ibid. 248.

of the most conspicuous and important distinctions between the urine of those who enjoy good and bad health *.

Urea,

10. If urine be evaporated by a slow fire to the consistence of a thick syrup, it assumes a deep brown colour, and exhales a fetid ammoniacal odour. When allowed to cool, it concretes into a mass of crystals, composed of all the component parts of urine. If four times its weight of alcohol be poured upon this mass, at intervals, and a slight heat be applied, the greatest part of it is dissolved. The alcohol, which has acquired a brown colour, is to be decanted off, and distilled in a crucible in a sand heat, till the mixture has boiled for some time, and acquired the consistence of a syrup. By this time the whole of the alcohol has passed off, and the matter, on cooling, crystallizes in quadrangular plates which intersect each other. This substance is *urea*, which composes $\frac{19}{20}$ of the urine, provided the watery part be excluded. To this substance the taste and smell of urine are owing. It is a substance which characterizes urine, and constitutes it what it is, and to which the greater part of the very singular phenomena of urine are to be ascribed.

It may be detected by evaporating urine to the consistence of a syrup, and pouring into it concentrated nitric acid. Immediately a great number of white shining crystals appear in the form of plates, very much resembling crystallized boracic acid. These crystals are urea combined with nitric acid.

The quantity of urea varies exceedingly in different urines. In the urine voided soon after a meal, very

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* Fourcroy and Vauquelin, *Ann. de Chim.* xxxi. 61.

little of it is to be found, and scarcely any at all in that which hysterical patients void during a paroxysm.

A resin,

11. According to Fourcroy and Vauquelin, the colour of urine depends upon the urea: the greater the proportion of urea the deeper the colour: But Proust has detected a resinous matter in urine similar to the resin of bile; and to this substance he ascribes the colour of urine. If urine, evaporated to the consistence of an extract, be mixed with sulphuric acid and distilled, this resin, he informs us, separates during the distillation. What is first obtained is soft, but the last portions are in the state of a dry powder. The consistence and colour of this resin resembles castor: it is very soluble in alcohol, and precipitated from its solution by water: But it is also soluble in water; and, according to Proust, is the resin of bile, somewhat modified by its passage through the urinary organs *.

Muriat of soda,

12. If urine be slowly evaporated to the consistence of a syrup, a number of crystals make their appearance on its surface: these possess the properties of muriat of soda. Urine therefore contains muriat of soda. It is well known that muriat of soda crystallizes in cubes; but when obtained from urine it has the form of octahedrons. This singular modification of its form is owing to the action of urea †. It has been long known that urine saturated with muriat of soda deposites that salt in regular octahedrons.

Phosphats of ammonia and of soda,

13. The saline residuum which remains after the separation of urea from crystallized urine by means of alcohol has been long known under the names of fusible salt of urine and microcosmic salt. Various methods

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* *Ann. de Chim.* xxxvi. 274.

† Fourcroy and Vauquelin.

of obtaining it have been given by chemists from Boerhaave, who first published a process, to Rouelle and Chaulnes, who gave the method just mentioned. If this saline mass be dissolved in a sufficient quantity of hot water, and allowed to crystallize spontaneously in a close vessel, two sets of crystals are gradually deposited. The lowermost set has the figure of flat rhomboidal prisms; the uppermost, on the contrary, has the form of rectangular tables. These two may be easily separated by exposing them for some time to a dry atmosphere. The rectangular tables effloresce and fall to powder, but the rhomboidal prisms remain unaltered.

When these salts are examined, they are found to have the properties of phosphats. The rhomboidal prisms consist of phosphat of ammonia united to a little phosphat of soda; the rectangular tables, on the contrary, are phosphat of soda united to a small quantity of phosphat of ammonia. Urine, then, contains phosphat of soda and phosphat of ammonia.

Muriat of ammonia,

14. When urine is cautiously evaporated, a few cubic crystals are often deposited among the other salts; these crystals have the properties of muriat of ammonia. Now the usual form of the crystals of muriat of ammonia is the octahedron. The change of its form in urine is produced also by urea. This salt is obtained in greater abundance when the crystals of urea obtained from the alcohol solution are distilled *.

And sulphur.

15. When urine is boiled in a silver bason it blackens the bason; and if the quantity of urine be large, small crusts of sulphuret of silver may be detached.

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* Fourcroy and Vauquelin.

Hence we see that urine contains sulphur. This sulphur exhales along with the carbonic acid when the urine putrefies; for the fumes which separate from urine in that state blacken paper stained with acetite of lead[*].

Its composition.

Urine, then, contains the following substances:

1. Water,
2. Phosphoric acid,
3. Phosphat of lime,
4. Phosphat of magnesia,
5. Carbonic acid,
6. Carbonat of lime,
7. Uric acid,
8. Rosaceous acid,
9. Benzoic acid,
10. Gelatine and albumen,
11. Urea,
12. Resin,
13. Muriat of soda,
14. Phosphat of soda,
15. Phosphat of ammonia,
16. Muriat of ammonia,
17. Sulphur.

Other substances occasionally present.

These are the only substances which are constantly found in healthy urine[†]; but it contains also occasionally other substances. Very often muriat of potass may be distinguished among the crystals which form during its evaporation. The presence of this salt may always be detected by dropping cautiously some tartarous acid into urine. If it contains muriat of potass, there will precipitate a little tartar, which may easily be recognised by its properties[‡].

Urine sometimes also contains sulphat of soda, and even sulphat of lime. The presence of these salts may be ascertained by pouring into urine a solution of muriat of barytes; a copious white precipitate appears, consisting of the barytes combined with phosphoric acid,

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[*] Proust, *Ann. de Chim.* xxxvi. 258.

[†] Fourcroy and Vauquelin, Ibid. xxxi. 69.

[‡] Cruikshank, *Phil Mag.* ii. 241.

and with sulphuric acid, if any be present. This precipitate must be treated with a sufficient quantity of muriatic acid. The phosphat of barytes is dissolved, but the sulphat of barytes remains unaltered *.

Putrefaction of urine.

No substance putrefies sooner, or exhales a more detestable odour, during its spontaneous decomposition, than urine; but there is a very great difference in this respect in different urines. In some, putrefaction takes place almost instantaneously as soon as it is voided; in others, scarcely any change appears for a number of days. Fourcroy and Vauquelin have ascertained that this difference depends on the quantity of gelatine and albumen which urine contains. When there is very little of these substances present, urine remains long unchanged; on the contrary, the greater the quantity of gelatine or albumen, the sooner does putrefaction commence. The putrefaction of urine, therefore, is, in some degree, the test of the health of the person who has voided it; for a superabundance of gelatine in urine always indicates some defect in the power of digestion †.

The rapid putrefaction of urine, then, is owing to the action of gelatine on urea. We have seen already the facility with which that singular substance is decomposed, and that the new products into which it is changed are, ammonia, carbonic acid, and acetous acid. Accordingly, the putrefaction of urine is announced by an ammoniacal smell. Mucilaginous flakes are deposited, consisting of part of the gelatinous matter. The phosphoric acid is saturated with ammonia, and the phosphat of lime, in consequence, is precipitated. Ammonia combines with the phosphat of magnesia, forms

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* Fourcroy, *Ann. de Chim.* vii. 183.

† Ibid. xxxi. 61.

with it a triple salt, which crystallizes upon the sides of the vessel in the form of white crystals, composed of six-sided prisms, terminated by six-sided pyramids. The uric and benzoic acids are saturated with ammonia; the acetous acid, and the carbonic acid, which are the products of the decomposition of the urea, are also saturated with ammonia; and notwithstanding the quantity which exhales, the production of this substance is so abundant, that there is a quantity of unsaturated alkali in the liquid. Putrefied urine, therefore, contains chiefly the following substances, most of which are the products of putrefaction:

Ammonia,
Carbonat of ammonia,
Phosphat of ammonia,
Phosphat of magnesia and ammonia,
Urat of ammonia,
Acetite of ammonia,
Benzoat of ammonia,
Muriat of soda,
Muriat of ammonia;

Besides the precipitated gelatine and phosphat of lime[*].

Distillation of urine.

The distillation of urine produces almost the same changes; for the heat of boiling water is sufficient to decompose urea, and to convert it into ammonia, carbonic and acetous acids. Accordingly, when urine is distilled, there comes over water, containing ammonia dissolved in it, and carbonat of ammonia in crystals; The acids contained in urine are saturated with ammonia, and the gelatine and phosphat of lime precipitate[†].

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[*] *Ann. de Chim.* xxxi. 70.

[†] Ibid. 55.

Changes occasioned in urine by diseases.

SUCH are the properties of human urine in a state of health: But this excretion is singularly modified by disease; and the changes to which it is liable have attracted the attention of physicians in all ages, because they serve in some measure to indicate the state of the patient, and the progress of the disease under which he labours. The following are the most remarkable of these changes that have been observed*.

1. In *inflammatory* diseases the urine is of a red colour, and peculiarly acrid; it deposites no sediment on standing, but with oxy-muriat of mercury it yields a copious precipitate.

2. During *jaundice* the urine has an orange yellow colour, and communicates the same tint to linen. Muriatic acid renders this urine green, and thus detects the presence of a little bile.

3. About the end of *inflammatory* diseases the urine becomes abundant, and deposites a copious pink-coloured sediment, composed of rosaceous acid, a little phosphat of lime, and uric acid.

4. During *hysterical* paroxysms, the urine usually flows abundantly. It is limpid and colourless, containing much salt, but scarcely any urea or gelatine.

5. At the commencement of *gouty* paroxysms, the urine, as Berthollet first observed, contains no excess of phosphoric acid, and scarcely any phosphat of lime. Towards the end of the paroxysm the phosphoric acid makes its appearance again, and the urine deposites the pink-coloured sediment. If this sediment suddenly disappears, a new fit may be expected.

6. In general *dropsy*, the urine is loaded with albu-

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[*] See Cruikshank, *Phil. Mag.* ii. 240. and Fourcroy, x. 166.

men, and becomes milky, or even coagulates when heated, or at least when acids are mixed with it. In dropsy from diseased liver, no albumen is present, the urine is scanty, high coloured, and deposites the pink-coloured sediment.

7. In *dyspepsia*, the urine always yields a copious precipitate with tan, and putrefies rapidly.

8. The urine of *rickety* patients is said to be loaded with phosphat of lime, or, according to others, with oxalat of lime.

9. In *diabetes*, the urine is sweet-tasted, and often loaded with saccharine matter. In one case, the urine emitted daily by a diabetic patient, according to the experiments of Cruikshank, contained 29 ounces of sugar.

Urine of the inferior animals.

THE urine of other animals differs considerably from that of man. For the analyses of the urine of quadrupeds hitherto made, we are chiefly indebted to Rouelle junior. The following facts have been ascertained by that chemist, and by the late experiments of Fourcroy and Vauquelin.

Urine of the horse.

I. The urine of the HORSE has a peculiar odour; after exercise it is emitted thick and milky; at other times it is transparent, but becomes muddy soon after its emission. When exposed to the air, its surface becomes covered with a crust of carbonat of lime. It gives a green colour to syrup of violets, and has the consistence of mucilage. The substances found in it by Rouelle, Fourcroy, and Vauquelin, are,

1. Carbonat of lime,
2. Carbonat of soda,
3. Muriat of potass,
4. Muriat of soda,
5. Benzoat of soda,
6. Urea.

Vhen muriatic acid is dropt into this urine concentra- ed, benzoic acid precipitates.

Urine of the cow.

II. The urine of the cow has a strong resemblance ɔ that of the horse; it has nearly the same odour, and ne same mucilaginous consistence. It tinges syrup of iolets green, and deposites a gelatinous matter. On tanding, small crystals are formed on its surface. It ontains, according to Rouelle,

1. Carbonat of potass,
2. Sulphat of potass,
3. Muriat of potass,
4. Benzoic acid,
5. Urea.

Urine of the camel.

III. The urine of the CAMEL was also examined by ₹ouelle. Its odour resembles that of the urine of the ow; its colour is that of beer; it is not mucilaginous, nd does not deposite carbonat of lime. It gives a green olour to syrup of violets, and effervesces with acids like he urine of the horse and cow. Rouelle obtained rom it,

1. Carbonat of potass,
2. Sulphat of potass,
3. Muriat of potass,
4. Urea.

Urine of the rabbit.

IV. The urine of the RABBIT has been lately analy- ed by Vauquelin. When exposed to the air, it be- omes milky, and deposites carbonat of lime. It gives ı green colour to syrup of violets, and effervesces with ıcids. That chemist detected in it the following sub- tances:

1. Carbonat of lime,
2. Carbonat of magnesia,
3. Carbonat of potass,
4. Sulphat of potass,
5. Sulphat of lime,
6. Muriat of potass,
7. Urea,
8. Gelatine,
9. Sulphur.

Urine fo the guinea pig.

V. Vauquelin has also made some experiments on the urine of the GUINEA PIG; from which it appears that it resembles the urine of the other quadrupeds. It deposites carbonat of lime, gives a green colour to syrup of violets, and contains carbonat and muriat of potass, but no phosphat nor uric acid *.

Thus it appears that the urine of the graminivorous quadrupeds agrees with the human in containing urea, but differs from it materially in being destitute of phosphoric acid, phosphats, and uric acid. Whether the urine of carnivorous quadrupeds contains these last substances has not been ascertained, but it is probable that it does.

SECT. XVIII.

OF URINARY CALCULI.

It is well known that concretions not unfrequently form in the bladder, or the other urinary organs, and occasion one of the most dismal diseases to which the human species is liable.

History.

These concretions were distinguished by the name of *calculi*, from a supposition that they are of a stony nature. They have long attracted the attention of physicians. Chemistry had no sooner made its way into medicine than it began to exercise its ingenuity upon the urinary calculi; and various theories were given of their nature and origin. According to Paracelsus, who gave them the ridiculous name of *duelech*, urinary

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* Fourcroy, x. 181.

Chap. II.

ılculi were composed of a mucilaginous tartar which
ɔated in the blood vessels. The schoolmen, on the other
ınd, considered them as a peculiar mucilage concocted
ıd petrefied by the heat of the body. These opinions
ere ably refuted by Van Helmont in his Treatise *de
ithiasi*, which contains the first attempt towards an ana-
sis of urine and urinary calculi; and, considering the
eriod at which it was written, is certainly possessed of
ıcommon merit*. He demonstrates that the materials
calculi exist in urine: he considers them as compo-
d of a volatile earthy matter and the saline spirit of
ine, which coagulates instantaneously when they com-
ne together; but which are prevented from combi-

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* Van Helmont's account of the experiments by which he detected the
surdity of the prevailing opinions concerning the calculus is as follows:
Contigit semel, quod cum heroinis, dynastarum uxoribus, adeoque et
n regina ipsa, a tertia post meridiem, usque in tertiam post mediam
ctem, Londini in aula Withal conversarer. Erant enim profesta bac-
ınalium in epiphaniis. Micturiebam autem, dum istæ mulieres me se-
n primum ad regiam deducerent; quare honestatis causa, ad mini-
ım horis duodecim lotium detinui. Dein reversus domum, non po-
, etiam inspectione accuratissima, vel atomum arenæ in lotio meo of-
dere. Nam timebam, ne supra modum diutius detenta, coctaque fo-
jam granulosa. Quare curiosus, minxi per sudarium. At urina erat
nunis ab omni sabulo. Ergo postridie mane, novam urinam trans
eum minxi: eamque in vitrea matula totidem horis (duodecim scili-
) detinui. Ac tandem vidi palam, adhærentem arenam æquabiliter
ɔersam, quaquaversus steterat urina: effuso denique lotio, tetigi di-
o arenam istam. Ac propria edoctus experientia, conclusi mecum.
od quia urina, a me micturiente, detenta per horas duodecim, non ta-
n sabulum contineret, nec ipse ejecissem: quodque alias, minore diei
tio, sabulum in lotio meo, ambiente mensis Januarii, condensatum, at-
: vitreæ conchæ affixum fuerat. Scivi certo certius, quod nequaquam
istud sabulum requireretur materiæ viscositas: quodque calor mem-
nullatenus efficeret coagulationem calculi. Indo domum progressus,
jeci a me doctrinam scholarum, ac statim apprehendit me veritas."—
Lithiasi, cap. ii. § 13.

ning in healthy people by the presence of what he calls *scoria*, which saturates the salt of urine*. Boyle extracted from calculi, by distillation, oil, and a great quantity of volatile salt. Boerhaave supposed them compounds of oil and volatile salts. Slare attempted a chemical analysis of them†. Hales extracted from them a prodigious quantity of air. He gave them the name of *animal tartar*, pointed out several circumstances in which they resemble common tartar, and made many experiments to find a solvent of them‡. Drs Whytt and Alston pointed out alkalies as solvents of calculi. It was an attempt to discover a more perfect solvent that induced Dr Black to make those experiments which terminated in the discovery of the nature of the alkaline carbonats.

Such was the state of the chemical analysis of calculus, when, in 1776, Scheele published a Dissertation on the subject in the *Stockholm Transactions*; which was succeeded by some remarks of Mr Bergman. These illustrious chemists completely removed the uncertainty which had hitherto hung over the subject, and ascertained the nature of the calculi which they examined. Since that time considerable additional light has been thrown upon the nature of these concretions by the labours of Austin, Walther, Brugnatelli, Pearson, and, above all, of Fourcroy and Vauquelin, who have lately analysed about 500 calculi, and ascertained the presence of several new substances which had not been suspected.

Description

Urinary calculi are usually spheroidal or egg-shaped; sometimes they are polygonous, or resemble a clustre of mulberries, and in that case they are distin-

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[*] *De Lithiasi*, p. 21.

[†] *Phil. Trans.* xvi. 140.

[‡] *Veget. Stat.* ii. 187.

uished by the epithet *moriform*. Their size is various ; ometimes they are very small, and sometimes as large s a goose-egg, or even larger. The colour of some of iem is a deep brown resembling that of wood. In ome cases they are white, and not unlike chalk ; in thers, of a dark grey, and hard. These different co- ours are often intermixed, and occur of various degrees f intensity. Their surface in some cases is polished ke marble ; in others, rough and unequal ; sometimes ey are covered with semitransparent crystals. Their ecific gravity varies from 1.213 to 1.976*.

Component parts.

The substances hitherto discovered in urinary calculi e the following :

1. Uric acid,
2. Urat of ammonia,
3. Phosphat of lime†,
4. Phosphat of magnesia-and-ammonia,
5. Oxalat of lime,
6. Silica,
7. An animal matter.

1. Uric acid.

1. The greater number of calculi consist of uric acid. ll those analysed by Scheele were composed of it en- rely. Of 300 calculi analysed by Dr Pearson, scarce- one was found which did not contain a considerable antity of it, and the greater number manifestly were rmed chiefly of it. Fourcroy and Vauquelin found also in the greater number of the 500 calculi which ey analysed.

The presence of this acid may be easily ascertained

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[*] Fourcroy, x. 213.

[†] Brugnatelli found also phosphat of lime, with excess of acid, in cal- i.—See *Ann. de Chim.* xxxii. 183.

by the following properties: The calculi formed of it are brown, polished, and resemble wood. A solution of potass or soda dissolves it readily, and it is precipitated by the weakest acids. The precipitate is soluble in nitric acid; the solution is of a pink colour, and tinges the skin red*.

2. Urat of ammonia.

2. Though both Scheele and Pearson evidently analysed calculi composed of urat of ammonia, this salt was first distinguished from uric acid by Fourcroy and Vauquelin. The calculi formed of it resemble those formed of uric acid; but they are usually composed of thin layers, and have the colour of a dish of coffee. Urat of ammonia is easily detected by its rapid solubility in fixed alkaline leys, and the odour of ammonia which is perceived during the solution. It is not so often present in urinary calculi as the last mentioned substance. No calculus has hitherto been found composed of it alone, except the very small polygonal calculi, several of which sometimes exist in the bladder together†.

3. Phosphat of lime.

3. Phosphat of lime was observed in calculi by Bergman; afterwards it was found in abundance by Pearson, and more lately by Fourcroy and Vauquelin. It is deposited in calculi in thin layers or grains cohering imperfectly. It is white, without lustre, friable, stains the hands, paper, and cloth. It has very much the appearance of chalk, breaks under the forceps, is insipid, and insoluble in water. It is soluble in nitric, muriatic, and acetous acids, and is again precipitated by ammonia, fixed alkalies, and oxalic acid. It is never alone in calculi. It is intimately mixed with a gelatinous matter, which remains under the form of a membrane

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* Pearson.

† Fourcroy, x. 224.

vhen the earthy part is dissolved by very diluted a-ids *.

4. Phosphat of magnesia and ammonia.

4. Phosphat of magnesia-and-ammonia was first de-ected in calculi by Fourcroy and Vauquelin. It pro-ably owes its existence to a commencement of putre-action of the urine in the bladder. It occurs in white, emitransparent, lamellar layers; sometimes it is cry-tallized on the surface of the calculi in prisms, or what re called *dog-tooth* crystals. Its powder is of a bril-iant white. It has a weak sweetish taste, it is some-vhat soluble in water, and very soluble in acids, though reatly diluted. Fixed alkalies decompose it, leaving agnesia undissolved.

It never forms entire calculi. Sometimes it is mix-d with phosphat of lime, and sometimes layers of it over uric acid or oxalat of lime. It is mixed with the ame gelatinous matter as phosphat of lime †.

5. Oxalat of lime.

5. Oxalat of lime, which was first detected by Four-rcy and Vauquelin, forms one of the most unaccount-ble and formidable ingredients of urinary calculi. It s the component part of certain calculi, which, from e inequality of their surface, have got the name of *oriform* or *mulberry-shaped* calculi. It is never alone, ut combined with a peculiar animal matter, and form-ng with it a very hard calculus, of a dark grey colour, ifficult to saw asunder, admitting a polish like ivory, xhaling, when sawed, an odour like that of semen. nsoluble and indecomposable by alkalies; soluble in ery diluted nitric acid, but slowly, and with difficulty. t may be decomposed by the carbonats of potass and oda. When burnt, it leaves behind a quantity of pure

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* Fourcroy, *Ann. de Chim.* xxxii. 218.

† Ibid. p. 219.

lime, amounting to one-third of its weight, which may be easily recognised by its properties[*].

6. Silica.

6. Silica has only been found in two instances by Fourcroy and Vauquelin, though they have analysed about 600 calculi. No other chemist has observed it. It must therefore be considered as a very uncommon ingredient of these concretions. In the two instances in which it occurred, it was mixed with phosphat of lime[†]. The two calculi containing it were moriform, but of a lighter colour than usual, extremely hard, and difficult to saw or reduce to powder. The presence of silica may be easily detected by its fusibility into glass with fixed alkalies, and its other well known properties.

7. Animal matter.

7. All calculi contain a peculiar animal matter, as is evident from their blackening, and exhaling an ammoniacal odour, when strongly heated. This matter appears to compose the cement which binds the different particles of the calculus together, and in all probability it is the cause which influences its formation. It is different in different calculi. In those composed of uric acid or urat of ammonia, it seems to be an albuminous substance mixed with urea. The earthy phosphats are contained between the layers of a membranous or cellular matter, composed most probably of coagulated albumen or gelatine. The oxalat of lime and silica have for their bases a membranous matter formed of layers, each of which is strong and dense, and seemingly composed of coagulated albumen[‡].

Such are the component parts of urinary calculi; but as these substances often occur mixed together in various

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[*] Fourcroy, *Ann. de Chim.* xxxii. 220.

[†] Ibid. p. 221.

[‡] Fourcroy, x. 233.

ays, it is a point of some consequence to be able to certain the component parts of the different calculi om their appearance, and to know what substances ually associate together; as this knowledge may lead reafter to the true theory of their formation, and us perhaps enable us to prevent that most dreadful of l diseases. Fourcroy and Vauquelin, after an examination of more than 600 calculi, have divided them to three genera and twelve species. The following a view of their arrangement.

Arrangement of the calculi.

GENUS I. *Calculi composed of one ingredient.*

Sp. 1. Uric acid.
Sp. 2. Urat of ammonia.
Sp. 3. Oxalat of lime.

GENUS II. *Calculi composed of two ingredients.*

Sp. 1. Uric acid and the phosphats in layers.
Sp. 2. Ditto mixed together.
Sp. 3. Urat of ammonia and the phosphats in layers.
Sp. 4. Ditto mixed together.
Sp. 5. The phosphats mixed or in layers.
Sp. 6. Oxalat of lime and uric acid in layers.
Sp. 7. Oxalat of lime and the phosphats in layers.

GENUS III. *Calculi containing more than three ingredients.*

Sp. 1. Uric acid or urat of ammonia, the phosphats, d oxalat of lime.

Sp. 2. Uric acid, urat of ammonia, the phosphats, lica.

Let us take a view of each of these species.

Description of the species.

Sp. 1. *Uric acid.* Colour that of wood, various shades of yellow or red. Texture laminar and radiated, compact and fine. Specific gravity from 1.5 to 1.786; sometimes so low as 1.276. Surface usually smooth and polished. Completely soluble in fixed alkaline leys, without emitting any odour of ammonia. This species is the most common. One fourth of the 600 calculi examined by Fourcroy and Vauquelin belonged to it.

Sp. 2. *Urat of ammonia.* Colour brownish white. Texture laminar, laminæ easily separated from each other. Specific gravity from 1.225 to 1.720. Surface often crystallized. Soluble in hot water, especially when reduced to powder. Soluble in fixed alkalies while ammonia is evolved. This species is uncommon.

Sp. 3. *Oxalat of lime.* Colour soot brown. Texture dense and hard resembling ivory. Surface unequal, and full either of pointed or rounded protuberances. Hence the epithet moriform, by which the calculi of this species are distinguished. Specific gravity from 1.428 to 1.976. When sawn, exhales the odour of semen. When calcined, leaves a residuum of carbonat of lime. Insoluble in alkalies; soluble with difficulty in acids. This species occurs frequently.

Sp. 4. *Uric acid and the phosphats in layers.* Surface white, like chalk, and friable or sparry, and semitransparent, according as the outermost coat is phosphat of lime or of magnesia. Often large. When cut, they present a nucleus of uric acid. Sometimes this nucleus is covered with alternate layers of the two phosphats. Specific gravity very variable. This species is not uncommon. About $\frac{1}{50}$ of the calculi examined by Fourcroy and Vauquelin belonged to it.

Sp. 5. *Uric acid and the phosphats mixed together.* This species varies in its appearance. Sometimes the mponent parts alternate in visible layers, at others ey are too thin to be perceived by the eye, and can nly be ascertained by analysis. Specific gravity from .213 to 1.739. This species is not uncommon. About of the calculi analysed by Fourcroy and Vauquelin elonged to it.

Sp. 6. *Urat of ammonia and the phosphats in layers.* his species resembles the fourth in its appearance, ut its nucleus instead of uric acid is composed of urat f ammonia. It is not very common, and the calculi elonging to it are smaller than those of the fourth ecies.

Sp. 7. *Urat of ammonia and the phosphats mixed.* his species resembles the fifth, but may be distinguish-d by a colour less yellow, and by the ammonia emitted hen the calculi are treated with potass. The calculi elonging to it are small and rather uncommon.

Sp. 8. *The two phosphats mixed or in layers.* Colour hite like chalk. Texture laminar; friable, easily se-arated, and staining the surface of other bodies like halk; often mixed with thin layers of phosphat of agnesia-and-ammonia, sparry and semitransparent. pecific gravity from 1.138 to 1.471. Soluble in acids, nsoluble in alkalies. About $\frac{1}{15}$ of the calculi examined y Fourcroy and Vauquelin belonged to this species.

Sp. 9. *Oxalat of lime and uric acid in layers.* The alculi belonging to this species have a nucleus of oxalat f lime, covered with a layer more or less thick of uric cid, or they consist of a small calculus of the third pecies, covered with a layer belonging to the first pecies. They are easily distinguished when sawn in wo. About $\frac{1}{10}$ of the 600 calculi analysed by Four-roy and Vauquelin belonged to this species.

Sp. 10. *Oxalat of lime and the phosphats in layers.* The calculi belonging to this species have a nucleus of oxalat of lime covered with a coat of the phosphats. Externally, therefore, they are the same with the fourth and eighth species; while the internal nucleus belongs to the third species. They are easily distinguished therefore when sawn in two. The calculi of this species are the most numerous of all next to those of the first species. About $\frac{1}{5}$ of those examined by Fourcroy and Vauquelin belonged to it.

Sp. 11. *Uric acid or urat of ammonia, the phosphats, oxalat of lime.* The calculi of this species have a nucleus of oxalat of lime, over this a coat of uric acid or urat of ammonia, or of a mixture of both; while the outermost coat is composed of the phosphats.

Sp. 12. *Uric acid, urat of ammonia, the phosphats, silica.* The calculi of this species bear a considerable resemblance to those of the last. The nucleus is composed of silica and phosphat of lime, then there is a root of uric acid and urat of ammonia, and over all a coat of the phosphats. Only two calculi of this kind have been observed.

From the preceding account of the different urinary calculi, it appears that all their component parts exist in urine, except oxalat of lime and silica. But little satisfactory is known concerning the manner in which these concretions are formed, or of the cause of their formation. Whenever any solid body makes its way into the bladder, it has been observed that it is soon encrusted with a coat of phosphat of lime; and this first nucleus soon occasions a calculus. Concretions of uric acid seldom or never form in the bladder, unless a primitive nucleus has originated in the kidneys. The gravel hich is so frequently emitted by persons threatened ith the stone, consists always of this acid. As oxalic id does not exist in urine, some morbid change must ke place in the urine when calculi composed of oxalat lime are deposited. Brugnatelli's discovery of the stantaneous conversion of uric acid into oxalic acid oxy-muriatic acid, which has been confirmed by the periments of Fourcroy and Vauquelin, throws consi- rable light upon the formation of oxalic acid in urine, shewing us that uric acid is probably the basis of it; it in what manner the change is actually produced, it not so easy to say.

Attempts to discover a solvent of calculi.

As our ignorance of the cause of urinary concretions its it out of our power to prevent their formation, e ingenuity of physicians has been employed in at- mpting to discover substances capable of dissolving em after they have formed, and thus to relieve the iman race from one of the most dreadful diseases to hich it is subject. These attempts must have been iin, or their success must have entirely depended up- chance, till the properties of the concretions them- lves had been discovered, and the substances capable dissolving them ascertained by experiment. I shall erefore pass over the numerous lithanthriptics which ve been recommended in all ages, and satisfy myself ith giving an account of the experiments made by urcroy and Vauquelin to dissolve stones by injections rough the urethra, made after their analysis of the inary calculi.

The component parts of urinary calculi, as far as sol- nts are concerned, may be reduced under three heads: Uric acid and urat of ammonia; 2. The phosphats; Oxalat of lime.

Solvents of the different component parts.

1. A solution of pure potass and soda, so weak that it may be kept in the mouth, and even swallowed without pain, soon dissolves calculi composed of uric acid, or urat of ammonia, provided they be kept plunged in it.

2. The phosphats are very quickly dissolved by nitric or muriatic acid, so weak that it may be swallowed without inconvenience, and possessed of no greater acridness than urine itself.

3. Oxalat of lime is much more difficult of solution than the preceding substances. Calculi composed of it are slowly dissolved by nitric acid, or by carbonat of potass or soda, weak enough not to irritate the bladder: but the action of these substances is slow, and scarcely complete.

Method of applying them.

These solvents, injected into the bladder repeatedly, and retained in it as long as the patient can bear their action without inconvenience, ought to act upon the stone, and gradually dissolve it. The difficulty, however, is to determine the composition of the calculus to be acted upon, in order to know which of the solvents to employ. But as no method of deciding this point with certainty is at present known, we must try some one of the dissolvents for once or twice, and examine it after it has been thrown out of the bladder. Let us begin, for instance, with injecting a weak solution of potass; and after it has remained in the bladder half an hour, or longer if the patient can bear it, let the liquid, as soon as passed, be filtered and mixed with a little muriatic acid; if any uric acid has been dissolved, a white solution will make its appearance. This precipitate is a proof that the calculus is composed of uric acid. If it does not appear, after persevering in the alkaline soluɔn for some days, then there is reason to expect the ·esence of the phosphats; of course a weak muriatic id solution should be injected. After this solution is ıitted, let it be mixed with ammonia, and the phos- ıat of lime will precipitate, if the calculus be compo- d of it. If neither of these solutions take up any ing, and if the symptoms are not alleviated, we must ıve recourse to the action of nitric acid, on the sup- ɔsition that the calculus is composed of oxalat of lime. hese different solutions must be persisted in, and va- ed occasionally as they lose their efficacy, in order to ssolve the different coats of the calculus. Such are ıe methods pointed out by Fourcroy and Vauquelin. is scarcely necessary to observe, that the bladder ıould be evacuated of urine previous to the injections; ıd that the injections should be previously heated to ıe temperature of the body.

Calculi of the inferior animals.

The calculi found in the bladder of other animals ıve not been examined with the same care. Some of ıem, however, have been subjected to an accurate ana- ·sis. No uric acid has ever been found in any of them. ourcroy found a calculus extracted from the kidney of horse composed of three parts of carbonat of lime, ıd one part phosphat of lime *. Dr Pearson exami- ɜd a urinary calculus of a horse; it was composed of ıosphat of lime and phosphat of ammonia. Brugna- lli found a calculus extracted from the bladder of a ɔw, which was exceedingly hard, composed of pure ırbonat of lime, inclosing a soft nucleus of a fetid and rinous odour †. Bartholdi examined another calculus f a pig, the specific gravity of which was 1.9300. It

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[*] *Ann. de Chim.* xvi. 95.

[†] Ibid. xxxii. 184.

consisted of phosphat of lime[*]. Dr Pearson found a calculus taken from the bladder of a dog composed of phosphat of lime, phosphat of ammonia, and an animal matter. He found the urinary calculus of a rabbit, of the specific gravity 2, composed of carbonat of lime and some animal matter[†].

Composition.

The composition of the different animal concretions hitherto examined may be seen in the following TABLE:

Horse.	1. Carbonat of lime and phosphat of lime[‡]. 2. Phosph. of lime and phosph. of ammonia[§]. 3. Carbonat of lime and animal matter[§].
Sow.	1. Carbon. of lime and an animal nucleus[‖]. 2. Phosphat of lime[¶].
Dog.	Phosphat of lime, and of ammonia, and animal matter[§].
Rabbit.	Carbonat of lime and animal matter[§].
Ox.	Carbonat of lime, gelatinous matter[‡].

THUS I have given an account of all those secretions which have been attentively examined by chemists. The remainder have been hitherto neglected; partly owing to the difficulty of procuring them, and partly on account of the multiplicity of other objects which occupied the attention of chemical philosophers. It remains for us now to examine by what processes these different secretions are formed, how the constant waste of living bodies is repaired, and how the organs themselves are nourished and preserved. This shall form the subject of the following Chapter.

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[*] *Ann. de Chim.* xxxii. 185.

[†] *Phil. Mag.* ii. 134.

[‡] Fourcroy.

[§] Pearson.

[‖] Brugnatelli and Fourcroy.

[¶] Bartholdi.

CHAP. III.

OF THE FUNCTIONS OF ANIMALS.

THE intention of the two last Chapters was to exhibit a view of the different substances which enter into the composition of animals, as far as the present limited state of our knowledge puts it in our power. But were our enquiries concerning animals confined to the mere ingredients of which their bodies are composed, even supposing the analysis as complete as possible, our knowledge of the nature and properties of animals would be imperfect indeed.

How are these substances arranged? How are they produced? What purposes do they serve? What are the distinguishing properties of animals, and the laws by which they are regulated?

Animals resemble vegetables.

Animals resemble vegetables in the complexness of their structure. Like them, they are machines nicely adapted for particular purposes, constituting one whole, and continually performing an infinite number of the most delicate processes. But neither an account of the structure of animals, nor of the properties which distinguish them from other beings, will be expected here: These topics belong entirely to the anatomist and physiologist. I mean in the present Chapter to take a view of those processes only that are concerned in the *production* of animal substances, which alone properly belong to Chemistry. The other functions are regulated by laws of a very different nature, which have no resemblance or analogy to the laws of Chemistry or Mechanics.

SECT. I.

OF DIGESTION.

Food necessary.

EVERY body knows that animals require food, and that they die sooner or later if food be withheld from them. There is indeed a very great difference in different animals, with regard to the quantity of food which they require, and the time which they can pass without it. In general, this difference depends upon the activity of the animal. Those which are most active require most, and those which move least require least food. The cause of this is also well known; the bodies of animals do not remain stationary, they are constantly wasting; and the waste is generally proportional to the activity of the animal. It is evident, then, that the body must receive, from time to time, new supplies, in place of what has been carried off. Hence the use of food, which answers this purpose.

Its nature.

2. We are much better acquainted with the food of animals than of vegetables. It consists of almost all the animal and vegetable substances which have been treated of in this and the preceding Book: for there are but very few of them which some animal or other does not use as food. Man uses as food chiefly the muscles of animals, the seed of certain grasses, and a variety of

egetable fruits. Almost all the inferior animals have articular substances on which they feed exclusively. ome of them feed on animals, others on vegetables. Ian has a greater range; he can feed on a very great umber of substances. To enumerate these substances vould be useless; as we are not able to point out with ccuracy what it is which renders one substance more ourishing than another.

Many substances do not serve as nourishment at all; nd not a few, instead of nourishing, destroy life. These ast are called *poisons*. Some poisons act chemically, by ecomposing the animal body. The action of others is ot so well understood.

Converted into chyme in the stomach.

3. The food is introduced into the body by the outh, and almost all animals reduce it to a kind of ulpy consistence. In man and many other animals this done in the mouth by means of teeth, and the saliva vith which it is there mixed; but many other animals rind their food in a different manner. After the food as been thus ground, it is introduced into the stomach, vhere it is subjected to new changes. The stomach is strong soft bag, of different forms in different animals: in man it has some resemblance to the bag of a *ag-pipe*. In this organ the food is converted into a oft pap, which has no resemblance to the food when rst introduced. This pap has been called *chyme*.

4. Since chyme possesses new properties, it is evident hat the food has undergone some changes in the stomach, and that the ingredients of which it was composed have entered into new combinations. Now in vhat manner have these changes been produced?

This change ascribed to the mechanical action of the stomach.

At first they were ascribed to the mechanical action f the stomach. The food, it was said, was still farther triturated in that organ; and being long agitated backwards and forwards in it, was at last reduced to a pulp. But this opinion, upon examination, was found not to be true. The experiments of Stevens, Reaumur, and Spallanzani, demonstrated, that the formation of chyme is not owing to trituration; for on inclosing different kinds of food in metallic tubes and balls full of holes, in such a manner as to screen them from the mechanical action of the stomach, they found, that these substances, after having remained a sufficient time in the stomach, were converted into chyme, just as if they had not been inclosed in such tubes. Indeed the opinion was untenable, even independent of these decisive experiments, the moment it was perceived that chyme differed entirely from the food which had been taken: that is to say, that if the same food were triturated mechanically out of the body, and reduced to pap of precisely the same consistence with chyme, it would not possess the same properties with chyme; for whenever this fact was known, it could not but be evident that the food had undergone changes in its composition.

Ascribed to fermentation,

The change of food into chyme therefore was ascribed by many to *fermentation*. This opinion is indeed very ancient, and it has had many zealous supporters among the moderns. When the word *fermentation* was applied to the change produced on the food in the stomach, the nature of the process called *fermentation* was altogether unknown. The appearances, indeed, which take place during that process had been described, and the progress and the result of it were known; but no attempt had been made to explain the cause of fermentation, or to trace the changes which take place during its continuance. All that could be meant, then, by aying that the conversion of food into chyme in the tomach is owing to fermentation, was merely, that the nknown cause which acted during the conversion of egetable substances into wine or acid, or during their utrefaction, acted also during the conversion of the ood into chyme, and that the result in both cases was recisely the same. Accordingly, the advocates for his opinion attempted to prove, that air was constantly enerated in the stomach, and that an acid was contantly produced: for it was the vinous and acetous ermentations which were assigned by the greater numer of physiologists as the cause of the formation of hyme. Some indeed attempted to prove that it was roduced by the putrefactive fermentation; but their umber was inconsiderable, compared with those who dopted the other opinion.

But without reason.

Our ideas respecting fermentation are now somewhat ore precise. It signifies a slow decomposition, which akes place when certain animal or vegetable substances re mixed together at a given temperature; and the onsequent production of particular compounds. If herefore the conversion of the food into chyme be owng to fermentation, it is evident that it is totally indeendent of the stomach any farther than as it supplies emperature; and that the food would be converted ino chyme exactly in the same manner, if it were redued to the same consistence, and placed in the same temerature out of the body. But this is by no means the ase; substances are reduced to the state of chyme in a hort time in the stomach, which would remain unalterd for weeks in the same temperature out of the body. This is the case with bones; which the experiments of tevens and Spallanzani have shewn to be soon digested in the stomach of the dog. Further, if the conversion of food into chyme were owing to fermentation, it ought to go on equally well in the stomach and œsophagus. Now, it was observed long ago by Ray and Boyle, that when voracious fish had swallowed animals too large to be contained in the stomach, that part only which was in the stomach was converted into chyme, while what was in the œsophagus remained entire; and this has been fully confirmed by subsequent observations.

Still farther, if the conversion were owing to fermentation, it ought always to take place equally well, provided the temperature be the same, whether the stomach be in a healthy state or not. But it is well known, that this is not the case. The formation of chyme depends very much on the state of the stomach. When that organ is diseased, digestion is constantly ill performed. In these cases, indeed, fermentation sometimes appears, and produces flatulence, acid eructations, &c. which are the well-known symptoms of indigestion. These facts have been long known; they are totally incompatible with the supposition, that the formation of chyme is owing to fermentation. Accordingly that opinion has been for some time abandoned, by all those at least who have taken the trouble to examine the subject.

Owing to the action of the gastric juice.

The formation of chyme, then, is owing to the stomach; and it has been concluded, from the experiments of Stevens. Reaumur, Spallanzani, Scopoli, Brugnatelli, Carimini, &c. that its formation is brought about by the action of a particular liquid secreted by the stomach, and for that reason called *gastric juice*.

That it is owing to the action of a liquid is evident; because, if pieces of food be inclosed in close ubes, they pass through the stomach without any far-her alteration than would have taken place at the ame temperature out of the body; but if the tubes be erforated with small holes, the food is converted into hyme.

Nature of the gastric juice.

This liquid does not act indiscriminately upon all ubstances: For if grains of corn be put into a perfora-ed tube, and a granivorous bird be made to swallow it, he corn will remain the usual time in the stomach with-ut alteration; whereas if the husk of the grain be pre-iously taken off, the whole of it will be converted into hyme. It is well known, too, that many substances ass unaltered through the intestines of animals, and onsequently are not acted upon by the gastric juice. his is the case frequently with grains of oats when ey have been swallowed by horses entire with their usks on. This is the case also with the seeds of ap-les, &c. when swallowed entire by man; yet these ery substances, if they have been previousy ground suf-ciently by the teeth, are digested. It appears, there-re, that it is chiefly the husk or outside of these sub-ances which resists the action of the gastric juice. We e also, that trituration greatly facilitates the conver-on of food into chyme.

The gastric juice is not the same in all animals; for any animals cannot digest the food on which others ve. The *conium maculatum* (hemlock), for instance, a poison to man instead of food, yet the goat often eeds upon it. Many animals, as sheep, live wholly up-n vegetables; and if they are made to feed on animals, eir stomachs will not digest them: others, again, as e eagle, feed wholly on animal substances, and cannot igest vegetables.

The gastric juice does not continue always of the same nature, even in the same animal: it changes gradually, according to circumstances. Graminivorous animals may be brought to live on animal food; and after they have been accustomed to this for some time, their stomachs become incapable of digesting vegetables. On the other hand, those animals which naturally digest nothing but animal food may be brought to digest vegetables.

5. What is the nature of the gastric juice which possesses these singular properties? It is evidently different in different animals; but it is a very difficult task, if not an impossible one, to obtain it in a state of purity. Various attempts have indeed been made by very ingenious philosophers to procure it; but their analysis of it is sufficient to shew us, that they have never obtained it in a state of purity.

Methods of procuring it.

The methods which have been used to procure gastric juice are, *first*, to kill the animal whose gastric juice is to be examined after it has fasted for some time. By this method Spallanzani collected 37 spoonfuls from the two first stomachs of a sheep. It was of a green colour, undoubtedly owing to the grass which the animal had eaten. He found also half a spoonful in the stomach of some young crows which he killed before they had left their nest.

Small tubes of metal pierced with holes, and containing a dry sponge, have been swallowed by animals; and when vomited up, the liquid imbibed by the sponge is squeezed out. By this method, Spallanzani collected 481 grains of gastric juice from the stomachs of five crows.

A *third* method consists in exciting vomiting in the norning, when the stomach is without food. Spallan- ani tried this method twice upon himself, and collect- d one of the times 1 oz. 32 gr. of liquid; but the ain was so great, that he did not think proper to try he experiment a third time. Mr Gosse, however, who ould excite vomiting whenever he thought proper, by wallowing air, has employed that method to collect gastric juice.

Spallanzani has observed, that eagles throw up every norning a quantity of liquid, which he considers as gas- ric juice; and he has availed himself of this to collect t in considerable quantities.

It is almost unnecessary to remark how imperfect hese different methods are, and how far every conclu- ion drawn from the examination of such juices must deviate from the truth. It is impossible that the gastric uice, obtained by any one of these processes, can be pure; because in the stomach it must be constantly mixed with large quantities of saliva, mucus, bile, food, &c. It may be questioned, indeed, whether any gastric uice at all can be obtained by these methods; for as the intention of the gastric juice is to convert the food into chyme, in all probability it is only secreted, or at least thrown into the stomach when food is present.

Attempts to analyse it.

We need not be surprised, then, at the contradictory accounts concerning its nature, given us by those philosophers who have attempted to examine it; as these relate not so much to the gastric juice, as to the different substances found in the stomach. The idea that the gastric juice can be obtained by vomiting, or that it is thrown up spontaneously by some animals, is, to say the least of it, very far from being probable.

According to Brugnatelli, the gastric juice of carnivorous animals, as hawks, kites, &c. has an acid and resinous odour, is very bitter, and not at all watery; and is composed of an uncombined acid, a resin, an animal substance, and a small quantity of muriat of soda[*]. The gastric juice of herbivorous animals, on the contrary, as goats, sheep, &c. is very watery, a little muddy, has a bitter saltish taste, and contains ammonia, an animal extract, and a pretty large quantity of muriat of soda[†]. Mr Carminati found the same ingredients; but he supposes that the ammonia had been formed by the putrefaction of a part of their food, and that in reality the gastric juice of these animals is of an acid nature[‡].

The accounts which have been given of the gastric juice of man are so various, that it is not worth while to transcribe them. Sometimes it has been found of an acid nature, at other times not. The experiments of Spallanzani are sufficient to shew, that this acidity is not owing to the gastric juice, but to the food He never found any acidity in the gastric juice of birds of prey, nor of serpents, frogs, and fishes. Crows gave an acidulous gastric juice only when fed on grain; and he found that the same observation holds with respect to dogs, herbivorous animals, and domestic fowls. Carnivorous birds threw up pieces of shells and coral without alteration; but these substances were sensibly diminished in the stomachs of hens, even when inclosed in perforated tubes. Spallanzani himself swallowed calcareous substances inclosed in tubes; and when he fed on vegetables and fruits, they were sometimes altered and a little diminished in weight, just as if they had been

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[*] Scopoli's Macquer's *Dict.*

[†] Ibid.

[‡] Senebier's *Observations on Gastric Juice.*

put into weak vinegar; but when he used only animal food, they came out untouched. According to this philosopher, whose experiments have been by far the most numerous, the gastric juice is naturally neither acid nor alkaline. When poured on the carbonat of potass, it causes no effervescence.

Such are the results of the experiments on the juices taken from the stomach of animals. No conclusion can be drawn from them respecting the nature of the gastric juice. But from the experiments which have been made on the digestion of the stomach, especially by Spallanzani, the following facts are established.

Its effect on the food.

The gastric juice attacks the surface of bodies, unites to the particles of them which it carries off, and cannot be separated from them by filtration. It operates with more energy and rapidity the more the food is divided, and its action is increased by a warm temperature. The food is not merely reduced to very minute parts; its taste and smell are quite changed; its sensible properties are destroyed, and it acquires new and very different ones. This juice does not act as a ferment; so far from it, that it is a powerful antiseptic, and even restores flesh already putrefied. There is not the smallest appearance of such a process; indeed, when the juice is renewed frequently, as in the stomach, substances dissolve in it with a rapidity which excludes all idea of fermentation. Only a few air-bubbles make their escape, which adhere to the alimentary matter, and buoy it up to the top, and which are probably extricated by the heat of the solution.

Substances found in the stomach.

With respect to the substances contained in the stomach, only two facts have been perfectly ascertained; The first is, that the juice contained in the stomach of oxen, calves, sheep, invariably contains uncombined phosphoric acid, as Macquart and Vauquelin have demonstrated: The second, that the juice contained in the stomach, and even the inner coat of the stomach itself, has the property of coagulating milk and the serum of blood. Dr Young found, that seven grains of the inner coat of a calf's stomach, infused in water, gave a liquid which coagulated more than 100 ounces of milk; that is to say, more than 6857 times its own weight; and yet, in all probability, its weight was not much diminished.

What the substance is which possesses this coagulating property, has not yet been ascertained; but it is evidently not very soluble in water: for the inside of a calf's stomach, after being steeped in water for six hours, and then well washed with water, still furnishes a liquor on infusion which coagulates milk *: And Dr Young found that a piece of the inner coat of the stomach, after being previously washed with water, and then with a diluted solution of carbonat of potass, still afforded a liquid which coagulated milk and serum.

It is evident, from these facts, that this coagulating substance, whatever it is, acts very powerfully; and that it is scarcely possible to separate it completely from the stomach. But we know at present too little of the nature of coagulation to be able to draw any inference from these facts. An almost imperceptible quantity of some substances seems to be sufficient to coagulate milk. For Mr Vaillant mentions in his Travels in Africa, that a porcelain dish which he procured, and which had lain for some years at the bottom of the sea, possessed, in

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* Young.

consequence, the property of coagulating milk when put into it; yet it communicated no taste to the milk, and did not differ in appearance from other cups.

It is probable that the saliva is of service in the conversion of food into chyme as well as the gastric juice. It evidently serves to dilute the food; and probably it may be serviceable also, by communicating oxygen.

Chyme converted into chyle and excrement.

6. The chyme, thus formed, passes from the stomach into the intestines, where it is subjected to new changes, and at last converted into two very different substances, chyle and excrementitious matter.

Nature chyle.

The *chyle* is a white-coloured liquid, very much resembling milk. It is exceedingly difficult to collect it in any considerable quantity, and for that reason it has never been accurately analysed. We know only in general that it resembles milk; containing, like it, an albuminous part capable of being coagulated, a serum, and globules which have a resemblance to cream*. It contains also different salts; and, according to some, a substance scarcely differing from the sugar of milk. Dr Charles Smith of New Jersey relates an instance of a dropsy of the abdomen in which the liquid accumulated appears to have been chyle. The patient, a boy twelve years of age, was tapped twice, and each time between seven and eight quarts of liquid abstracted. Its colour was chalky-white, and resembled milk pretty nearly, both in its taste, smell, and appearance. On standing a night, it threw up a good cream, though not so much in proportion as cow's milk usually does†.

Its formation a chemical process.

7. Concerning the process by which chyle is formed from chyme, scarcely any thing is known. It does not

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* Fordyce on *Digestion*, p. 121.

† *Phil. Mag.* ix. 16

appear that the chyme is precisely the same in all animals; for those which are herbivorous have a greater length of intestine than those which are carnivorous. It is certain that the formation of the chyle is brought about by a chemical change, although we cannot say precisely what that change is, or what the agents are by which it is produced. But that the change is chemical, is evident, because the chyle is entirely different, both in its properties and appearance, from the chyme. The chyme, by the action of the intestines, is separated into two parts, chyle and excrement: the first of which is absorbed by a number of small vessels called *lacteals;* the second is pushed along the intestinal canal, and at last thrown out of the body altogether.

After the chyme has been converted into chyle and excrement, although these two substances remain mixed together, it does not appear that they are able to decompose each other; for persons have been known seldom or never to emit any excrementitious matter *per anum* for years. In these, not only the chyle, but the excrementitious matter also, was absorbed by the lacteals; and the excrement was afterwards thrown out of the body by other outlets, particularly by the skin: in consequence of which, those persons have constantly that particular odour about them which distinguishes excrement. Now in these persons, it is evident that the chyle and excrement, though mixed together, and even absorbed together, did not act on each other; because these persons have been known to enjoy good health for years, which could not have been the case had the chyle been destroyed.

Use of the bile.

It has been supposed by some that the decomposition of the chyme, and the formation of chyle, is produced by the agency of the bile, which is poured out abundantly, and mixed with the chyme, soon after its enentrance into the intestines. If this theory were true, no chyle could be formed whenever any accident prevented the bile from passing into the intestinal canal: but this is obviously not the case; for frequent instances have occurred of persons labouring under jaundice from the bile ducts being stopped, either by gallstones or some other cause, so completely, that no bile could pass into the intestines; yet these persons have lived for a considerable time in that state. Consequently digestion, and therefore the formation of chyle, must be possible, independent of bile.

The principal use of the bile seems to be to separate the excrement from the chyle, after both have been formed, and to produce the evacuation of the excrement out of the body. It is probable that these substances would remain mixed together, and that they would perhaps even be partly absorbed together, were it not for the bile, which seems to combine with the excrement, and by this combination to facilitate its separation from the chyle, and thus to prevent its absorption. Fourcroy supposes that the bile, as soon as it is mixed with the contents of the intestinal canal, suffers a decomposition; that its alkali and saline ingredients combine with the chyle, and render it more liquid, while its albumen and resin combine with the excrementitious matter, and gradually render them less and less fluid; and this theory is certainly very probable *. The bile also stimulates the intestinal canal, and causes it to evacuate its contents sooner than it otherwise

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* Fourcroy, x. 48.

would do; for when there is a deficiency of bile, the body is constantly costive.

Excrementitious matter.

8. The excrementitious matter, then, which is evacuated *per anum*, consists of all that part of the food and chyme which was not converted into chyle; entirely altered, however, from its original state, partly by the decomposition which it underwent in the stomach and intestines, and partly by its combination with the resin and albumen of the bile. Accordingly we find in it many substances which did not exist at all in the food. Thus in the dung of cows and horses there is found a very considerable quantity of benzoic acid. The excrements of animals have not yet been subjected to an accurate analysis, though such an analysis would throw much light upon the nature of digestion. For if we knew accurately the substances which were taken into the body as food, and all the new substances which were formed by digestion; that is to say, the component parts of chyle and of excrement, and the variation which different kinds of food produce in the excrement, it would be a very considerable step towards ascertaining precisely the changes produced on food by digestion.

Vauquelin has ascertained that the fæces are constantly acid, always reddening vegetable blues. They run very quickly into fermentation, becoming at first more acid, but very soon begin to exhale ammonia. Pigeon dung contains an acid of a peculiar nature, which increases when the matter is diluted with water; but gradually gives place to ammonia, which is at last exhaled in abundance*.

To the same excellent chemist we are indebted for

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* Fourcroy, x. 70.

Excrements of fowls.

an analysis of the fixed parts of the excrements of fowls, and a comparison of them with the fixed parts of the food; from which some very curious consequences may be deduced.

He found that a hen devoured in ten days 11111.843 grains troy of oats. These contained

136.509 gr. of phosphat of lime
219.548 silica

356.057

During these ten days she layed four eggs; the shells of which contained 98.776 gr. phosphat of lime, and 453.417 gr. carbonat of lime. The excrements emitted during these ten days contained 175.529 gr. phosphat of lime, 58.494 gr. of carbonat of lime, and 185.266 gr. of silica. Consequently the fixed parts thrown out of the system during these ten days amounted to . . . . 274.305 gr. phosphat of lime
511.911 carbonat of lime
185.266 silica

Given out 971.482
Taken in 356.057

Surplus 615.425

Consequently the quantity of fixed matter given out of the system in ten days exceeded the quantity taken n by 615.425 grains.

The silica taken in amounted to 219.548 gr.
That given out was only . . . . 185.266 gr.

Remains 34.282

Consequently there disappeared 34.282 grains of silica.

The phosphat of lime taken in was	136.509 gr.
That given out was	274.305 gr.
	137.796

Fowls seem to form lime and phosphorus.

Consequently there must have been formed, by digestion in this fowl, no less than 137.796 grains of phosphat of lime, besides 511.911 grains of carbonat. Consequently lime (and perhaps also phosphorus) is not a simple substance, but a compound, and formed of ingredients which exist in oat-seed, water, or air, the only substances to which the fowl had access. Silica may enter into its composition, as a part of the silica had disappeared; but if so, it must be combined with a great quantity of some other substance *.

These consequences are too important to be admitted without a very rigorous examination. The experiment must be repeated frequently, and we must be absolutely certain that the hen has no access to any calcareous earth, and that she has not diminished in weight; because in that case some of the calcareous earth, of which part of her body is composed, may have been employed. This rigour is the more necessary, as it seems pretty evident, from experiments made long ago, that *some* birds at least cannot produce eggs unless they have access to calcareous earth. Dr Fordyce found, that if the canary bird was not supplied with lime at the time of her laying, she frequently died, from her eggs not coming forward properly †. He divided a number of these birds at the time of their laying eggs into two parties: to the one he gave a piece of old mortar, which the little animals swallowed greedily; they laid their

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* *Ann. de Chim.* xxix. 16.

† *On Digestion*, p. 25.

eggs as usual, and all of them lived; whereas many of the other party, which were supplied with no lime, died *.

Chyle mixes with lymph,

9. The chyle, after it has been absorbed by the lacteals, is carried by them into a pretty large vessel, known by the name of *thoracic duct*. Into the same vessel likewise is discharged a transparent fluid, conveyed by a set of vessels which arise from all the cavities of the body. These vessels are called *lymphatics*, and the fluid which they convey is called *lymph*. In the thoracic duct, then, the chyle and the lymph are mixed together.

Very little is known concerning the nature of the *lymph*, as it is scarcely possible to collect it in any quantity. It is colourless, has some viscidity, and is said to be specifically heavier than water. It is said to be coagulable by heat; if so, it contains albumen; and, from its appearance, it probably contains gelatine. Its quantity is certainly considerable, for the lymphatics are very numerous.

And is conveyed to the lungs.

10. The chyle and lymph being thus mixed together, are conveyed directly into the blood vessels. The effect produced by their union in the thoracic duct is not known, but neither the colour nor external properties of the chyle is altered. In man, and many other animals, the thoracic duct enters at the junction of the left subclavian and carotid veins, and the chyle is conveyed directly to the heart, mixed with the blood, which already exists in the blood vessels. From the heart, the blood and chyle thus mixed together are propelled into the lungs, where they undergo farther changes.

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* *On Digestion*, p. 26.

Book V.

SUCH are the phenomena of digestion, as far as they have been traced. The food is first conveyed to the stomach, where by means of the gastric juice it is converted into chyme. The chyme passes into the intestinal canal, where it is subjected to a new process, being gradually decomposed and converted into chyle and excrementitious matter, which by means of the bile are separated from each other. The excrementitious matter is evacuated, but the chyle is absorbed by the lacteals, and conveyed to the blood vessels and lungs. Let us now endeavour to trace the changes produced on it by these organs.

SECT. II.

OF RESPIRATION.

Respiration necessary.

THE absolute necessity of *respiration*, or of something analogous, is known to every one; and few are ignorant that in man, and hot blooded animals, the organ by which respiration is performed is the lungs. Now respiration consists in drawing a certain quantity of air into the lungs, and throwing it out again alternately. Whenever this function is suspended, even for a very short time, the animal dies.

The fluid respired by animals is common atmospherical air; and it has been ascertained by experiment, that no other gaseous body with which we are acquainted can be substituted for it. All the known gases have been tried; but they all prove fatal to the animal which is made to breathe them. Gaseous bodies, as far as respiration is concerned, may be divided into two classes: 1. Unrespirable gases; 2. Respirable gases.

Unrespirable gases.

I. The gases belonging to the first class are of such a nature that they cannot be drawn into the lungs of an animal at all; the epiglottis closing spasmodically whenever they are applied to it. To this class belong carbonic acid, and all the other acid gases, as has been ascertained by the experiments of Rozier.

Respirable gases of four kinds.

1. Suffocate.

2. Kill by occasioning changes in the blood.

3. Support life imperfectly.

4. May be breathed without injury.

II. The gases belonging to the second class may be drawn into the lungs, and thrown out again without any opposition from the respiratory organs; of course the animal is capable of respiring them. They may be divided into four subordinate classes: 1. The first set of gases occasion death immediately, but produce no visible change in the blood. They occasion the animal's death merely by depriving him of air, in the same way as he would be suffocated by being kept under water. The only gases which belong to this class are *hydrogen* and *azotic*.—2. The second set of gases occasion death immediately, but at the same time they produce certain changes in the blood, and therefore kill not merely by depriving the animal of air, but by certain specific properties. The gases belonging to this class are *carbonated hydrogen*, *carbonic oxide*, and perhaps also *nitrous gas*.—3. The third set of gases may be breathed for some time without destroying the animal, but death ensues at last, provided their action be long enough continued. To this class belong the oxide of azot and oxygen gas*.—4. The fourth set may be breathed any length of time without injuring the ani-

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* Perhaps also nitrous gas might have the same effect if it could be breathed by an animal whose lungs contained no oxygen.

mal. *Air* is the only gaseous body belonging to this class.

Oxygen necessary in respiration.

It has been long known that an animal can only breathe a certain quantity of air for a limited time; after which it becomes the most deadly poison, and produces suffocation as effectually as the most noxious gas, or a total absence of air. It was suspected long ago that this change is owing to the absorption of a part of the air; and Mayow made a number of very ingenious experiments in order to prove the fact. Dr Priestley and Mr Scheele demonstrated, that the quantity of oxygen gas in atmospheric air is diminished; and Lavoisier demonstrated, in 1776, that a quantity of carbonic acid gas, which did not previously exist in it, was found in air after it had been for some time respired. It was afterwards proved by Lavoisier, and many other philosophers who confirmed and extended his facts, that no animal can live in air totally destitute of oxygen. Even fish, which do not sensibly respire, die very soon if the water in which they live be deprived of oxygen gas. Frogs, which can suspend their respiration at pleasure, die in about forty minutes, if the water in which they have been confined be covered over with oil [*]. Insects and worms, as Vauquelin has proved, exhibit precisely the same phenomena. They require air as well as other animals, and die like them if they be deprived of it. They diminish the quantity of oxygen in the air in which they live, and give out, by respiration, the very same products as other animals. Worms, which are more retentive of life than most other animals, or at least not so much affected by poi-

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[*] Carradori, *Ann. de Chim.* xxix. 171.

sonous gases, absorb every particle of the oxygen contained in the air in which they are confined before they die. Mr Vauquelin's experiments were made on the *gryllus viridissimus*, the *limax flavus*, and *helix pomatia* *.

The quantity of air respired differs very much in different animals. Man and hot-blooded animals are under the necessity of breathing constantly; whereas amphibious animals have a certain power over respiration, and can suspend the function altogether for a limited time. Dr Barclay has ascertained that these animals acquire a much greater command over their respiratory organs by habit. Fish do not breathe at all, and consume so little air, that the small portion of it held in solution by the water in which they swim is sufficient for them. It appears that the number of respirations made in a given time differ considerably in different men. Dr Hales reckons them at 20 in a minute. Mr Davy informs us that he makes between 26 and 27 in a minute. I myself make about 20 at an average. Now 20 in a minute make 28,800 in 24 hours.

Number of respirations.

The quantity of air drawn in and emitted at every respiration must differ considerably with the size of the man and the capacity of his lungs. Dr Menzies found that a man draws in at a medium 43.77 cubic inches of air at every inspiration. From the experiments of Dr Goodwyn, it appears, that after a natural expiration, the mean quantity of air which remains in the lungs amounts to 109 cubic inches. Mr Davy has ascertained that his lungs, after a forced expiration, still

Quantity of air respired.

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* *Ann. de Chim.* xii. 278.

retain 41 cubic inches of air; after a natural expiration they contain . . . . . 118 cubic inches
After a natural inspiration 135
After a forced inspiration 254

By a full forced expiration, after a forced inspiration, he threw out . . . . 190 cubic inches
After a natural inspiration 78.5
After a natural expiration 67.5

Let us now endeavour to trace the changes produced by respiration. These are of two kinds, namely, 1. The changes produced upon the air respired. 2. Changes produced upon the blood exposed to this air. Each of these naturally claims our attention.

Changes produced on the air respired.

I. For our knowledge of the changes produced upon the air by respiration, we are chiefly indebted to Priestley, Cigna, Menzies, Lavoisier and Seguin, and Mr Davy. These changes are the following. 1. Part of the air respired disappears. 2. It becomes impregnated with carbonic acid. 3. It is loaded with water in the state of vapour.

1. Part of it is decomposed.

1. From the experiments of Dr Menzies, it follows that one twentieth of the air inspired disappears in the lungs. This agrees pretty nearly with the experiments made with great care by Lavoisier; an account of which he was employed in drawing up when he was unfortunately cut off by orders of the French government. Neither do the experiments published lately by Mr Davy, and which appear to have been performed with much precision, differ much from those of Dr Menzies. According to Davy about $\frac{1}{13}$th of the air inspired disappears during respiration.

Concerning the portion of the air which disappears, it has hitherto been the general opinion that it is the oxygen only, and that the azot remains the same after respiration as before it. These conclusions were the consequence of the experiments of Lavoisier, who announced the non-alteration of the azot of the atmosphere at a very early period of his researches. This conclusion seems to have been the consequence of the opinion which he entertained that air is merely a mechanical mixture of the two gases, oxygen and azotic; for when he first adopted it, his apparatus was not delicate enough to measure small changes; and he does not appear to have afterwards examined the azotic residuum with much attention. Mr Davy has rendered it probable that a portion of the azot of the air as well as its oxygen disappears during respiration.

Quantity absorbed.

According to Dr Menzies, at every respiration 2.1885 cubic inches of oxygen gas are consumed. Now 2.1885 cubic inches of that gas amount to 0.68669 gr. troy. Supposing, with Hales, that a man makes 1200 respirations in an hour, the quantity of oxygen gas consumed in an hour will amount to 824.028 grains, and in 24 hours to 19776.672 grains, or 41.2014 ounces troy. This quantity exceeds that found by other chemists considerably; but the allowance of oxygen for every respiration is rather too great. Indeed, from the nature of Dr Menzies's apparatus, it was scarce possible to measure it accurately. According to the last experiments of Lavoisier and Seguin, a man, at an average, consumes, in twenty-four hours, by respiration, 32.48437 ounces troy of oxygen gas; that is to say, that a quantity of oxygen gas, equal to that weight, disappears from the air which he respires in 24 hours. According to Mr Davy, the average quantity of air which disappears during every respiration is 1.4 cubic inch; of which 0.2 are azot and 1.2 oxygen. This, allowing 26 respirations per minute, as was the case with Mr Davy the subject of the experiment, amounts in 24 hours to rather more than 38 ounces of air; or precisely to 4.68 oz. azot, and 33.54 of oxygen *. This does not differ far from the result obtained by Lavoisier, excepting in the azot which the French chemist neglected altogether. We may consider it therefore as approximating to the truth as nearly as can be expected in the present state of the science.

2. Carbonic acid gas emitted.

2. That the air thrown out of the lungs contains carbonic acid may be easily ascertained by blowing it through a tube into lime water, which immediately becomes milky; and the bulk of the gas may be estimated by putting a portion of air from the lungs into a graduated jar standing over mercury, introducing a little barytic water, or pure soda, to absorb the carbonic acid, and observing the diminution of bulk in consequence of this absorption. According to Lavoisier, a man in 24 hours throws out from his lungs at an average about 15.73 oz. troy of carbonic acid. From the experiments of Mr Davy, on the other hand, it follows, that at every expiration about 1.1 cubic inch of carbonic acid is emitted, which amounts in 24 hours to no less than 37 ounces †. The difference between these two sets of experiments is enormous, and claims a more complete experimental investigation to determine whether the proportion of this gas emitted by different individuals, or by the same individual at different times, does not differ essentially. This supposition is surely very probable, as it tallies with what we know to be the

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* Davy's *Researches*, p. 433.

† Ibid.

case in other excretions; and if it prove true, would throw more light upon the nature of respiration than any thing which has hitherto been ascertained. In the mean time, till farther experiments decide the point, I think we may consider Mr Davy's conclusions as nearest the medium of the two, because they correspond with the earlier experiments of Lavoisier, and remove a very striking anomaly which appears when we compare Lavoisier's experiments on the respiration of the guinea-pig with those on the respiration of man. He put a guinea-pig into 708.989 grains troy of oxygen, and after the animal had breathed the gas for an hour, he took it out. He found that the oxygen gas now amounted only to . . . . 592.253 gr.
Consequently there had disappeared . . . 116.736
The carbonic acid gas formed was 130.472

The guinea-pig consumed in 24 hours 5.8368 oz. troy of oxygen gas, and emitted . . . . . . 6.5236 oz. of carbonic acid gas. Man, on the other hand, consumes in the same time . . . . 32.48437 oz. of oxygen gas, and emits only . . . . . . 15.73 oz. of carbonic acid gas. The oxygen gas consumed by the pig is to the carbonic gas emitted as 1.00 : 1.12; whereas in man it is as 1.000 : 0.484. If we could depend upon the accuracy of each of these experiments, they would prove, beyond a doubt, that the changes produced by the respiration of the pig are different, at least in degree, from those produced in man; but it is more than probable that some mistake has crept into one or other of the experiments.

3. Water emitted.

3. It is not so easy to determine the proportion of water emitted from the lungs mixed with the air expired, as it is that of the carbonic acid. According to

the experiments of Dr Hales, it amounts in a day to 20.4 oz.*; but his method was not susceptible of great accuracy. Mr Lavoisier, on the other hand, estimates it at 28.55 ounces; but this proportion seems rather to have been the result of calculation than of any direct measurement. It can only be considered therefore as an approximation to the truth, and most probably a very imperfect one.

Changes produced on the blood.

II. Let us now endeavour to ascertain the changes produced on the blood by respiration. The whole of the blood is propelled from the heart to the lungs, circulates through the vessels of that organ, and during that circulation it is exposed to the influence of the air which the animal is constantly drawing into the lungs. Now certain changes are produced upon it by this action, which have been partly traced by the experiments of Priestley, Cigna, Fourcroy, Hassenfratz, Beddoes, Watt, and above all by those of Mr Davy. These changes, as far as we are acquainted with them, are the following: 1. The blood absorbs air. 2. It acquires a florid red colour, and the chyle disappears. 3. It emits carbonic acid, and perhaps carbon. 4. It emits water, and perhaps hydrogen.

Theory of Priestley

1. Dr Priestley, the first of the modern chemists who turned his attention to respiration, concluded from some of his earliest experiments, that the blood, as it passed through the lungs, gave out phlogiston to the air, which was expired loaded with that substance, and of course that the purpose of respiration was to free the blood of phlogiston. Lavoisier soon after ascertained with more precision the changes which the air undergoes during

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* *Veget. Stat.* ii 327.

respiration; and he formed a theory in order to explain that function, assuming as its basis that all the changes produced on the air inspired are produced in the lungs; and of course, that all the new substances expired are formed in the lungs. According to him, the blood absorbs no air in the lungs; but it gives out hydrogen and carbon, which, combining with the oxygen of the air inspired, form water and carbonic acid. This theory was adopted by La Place, Crawford, Gren, and Girtanner, with a small variation. Indeed it does not differ, except in detail, from the original hypothesis of Dr Priestley, that the use of respiration is to rid the blood of phlogiston; for if we substitute carbon and hydrogen for phlogiston, the two theories precisely agree. Mr Lavoisier attempted not to prove its truth; he only tried to shew that the oxygen absorbed corresponds exactly with the quantity of oxygen contained in the carbonic acid and the water emitted. Now as this coincidence cannot be proved, the theory is entirely destitute of proof, as far as the proof depends upon this coincidence.

Modified by Lavoisier.

Theory of La Grange.

A different theory was afterwards proposed by Mr De La Grange. According to this philosopher, the oxygen gas, which disappears, combines with the blood as it passes through the lungs*; and at the instant of this combination, there is set free from the blood a quantity of carbonic acid gas and of water, which are thrown out along with the air expired. This theory was adopted and illustrated by Mr Hassenfratz, who succeeded in shewing its superiority to the theory maintained by Lavoisier and his associates.

But the plausibility of this theory depended entirely on the supposition that the oxygen of the air inspired was alone diminished, while the azot continued unaltered. Whenever this supposition could be proved a mistake, the theory of course fell to the ground. Now this has been done by the experiments of Mr Davy, who has rendered it probable that the azot is partly absorbed as well as the oxygen. Of course the theory of La Grange cannot be admitted: neither is the theory of Lavoisier more consistent with these experiments.

Experiments of Davy.

Air absorbed by the blood.

As the azot which has separated from the air during respiration is not to be found in the products of respiration, we must conclude that it has been absorbed by the blood. The experiments of Mr Davy have rendered it exceedingly probable that the air is absorbed unaltered by the blood; that it is afterwards decomposed by that liquid; and that the portion of azot, which is useless, is given out again, and mixed with the air in the lungs. The following facts render this opinion probable: When hydrogen gas is respired, no part of it is absorbed or disappears, nor are any positive changes produced on the blood. But when the gaseous oxide of azot is respired, it diminishes in quantity, while at the same time carbonic acid is evolved as usual, and a quantity of azotic gas makes its appearance. Now, as this azotic gas did not exist separately in the air before respiration, it must have been produced by the decomposition of the oxide of azot; but its quantity being much less than the azot contained in the oxide of azot which had disappeared, it follows that at least a part of this last gas had been absorbed by the blood unaltered; and if a part be thus absorbed, why not the whole? In that case the azotic gas must have been separated from the blood, in consequence of the subsequent decomposition of the oxide of azot absorbed. Now, as air is composed of precisely the same ingredients with the oxide of azot, and as a portion of the azot, as well as of the oxygen of the air respired, disappears, it is reasonable to suppose that the air is absorbed by the blood, and that the azotic gas which is developed is thrown out of the blood in consequence of the decomposition of the air absorbed. But farther, if the oxygen of air were alone absorbed by the blood during respiration while the azot remains unaltered, oxygen gas ought to answer the same purposes as air. This gas, however, cannot be respired without occasioning death at last. And when it is respired, the proportion of oxygen which disappears in a given time is much smaller than when air is respired. Thus when 182 cubic inches of oxygen gas were breathed by Mr Davy for half a minute, 11.4 cubic inches of the gas disappeared, whereas 15.6 cubic inches disappear in the same time when common air is respired*. This is a demonstration that the whole of air is useful in respiration, and not merely its oxygen. And if so, the air must be absorbed.

Blood acquires a scarlet colour.

2. It has been long known that the blood which flows in the veins is of a dark reddish purple colour, whereas the arterial blood is of a florid scarlet colour. Lower observed that the colour of the veinous blood was converted into that of arterial during its passage through the lungs. No chyle can be distinguished by its white colour in the blood after it has passed through the lungs. The changes, then, which take place upon the appearance of the blood are two: 1. It acquires a florid red colour; 2. The chyle totally disappears. Lower

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* Davy's *Researches*, p. 440.

himself knew that the change was produced by the air, and Mayow attempted to prove that it was by absorbing a part of the air. But it was not till Dr Priestley discovered that veinous blood acquires a scarlet colour when put in contact with oxygen gas, and arterial blood a dark red colour when put in contact with hydrogen gas, or, which is the same thing, that oxygen gas instantly gives veinous blood the colour of arterial; and hydrogen, on the contrary, gives arterial blood the colour of veinous blood—it was not till then that philosophers began to attempt any thing like an explanation of the phenomena of respiration.

Action of different gases on blood.

The blood is a fluid of so complex a nature that it is not easy to ascertain the changes produced in it by exposure to different gases out of the body; and even if that could be done, we have no method of proving that the effects of these gaseous bodies upon the coagulated blood are the same as they would be on the blood in its natural state, circulating in the vessels of a living animal. The facts which have been ascertained are the following:

1. Oxygen,

1*st*, It appears from the experiments of Priestley, Girtanner, and Hassenfratz, that when veinous blood is exposed to oxygen gas confined over it, the blood instantly assumes a scarlet colour, and the gas is diminished in bulk; therefore part of the gas has been absorbed. Mr Davy indeed could not perceive any sensible diminution of the bulk of the gas.

2 Air,

2*d*, The same change of colour takes place when blood is exposed to common air; and in that case the diminution of the bulk of the air is rather more sensible.

3. Azotic,

3*d*, Veinous blood exposed to the action of azotic gas continues unaltered in colour; neither does any perceptible diminution of the gas ensue.

4. Nitrous,

4*th*, Veinous blood exposed to the action of nitrous gas becomes of a deep purple, and about $\frac{1}{8}$ of the gas is absorbed.

5. Oxide of azot,

5*th*, Veinous blood exposed to oxide of azot becomes of a brighter purple, especially on the surface, and a considerable portion of the gas is absorbed.

6. Carbonic acid,

6*th*, Veinous blood exposed to carbonic acid gas becomes of a brownish-red colour, much darker than usual, and the gas is slightly diminished in bulk.

7. Carbonated hydrogen.

7*th*, Carbonated hydrogen gas gives veinous blood a fine red colour, a shade darker than oxygen gas does, as was first observed by Dr Beddoes, and at the same time a small portion of the gas is absorbed. This gas has the property of preventing, or at least greatly retarding the putrefaction of blood, as was first observed by Mr Watt*.

Arterial blood darkened by azotic and carbonic acid gas;

8*th*, When arterial blood is put in contact with azotic gas, or carbonic acid gas, it gradually assumes the dark colour of veinous blood, as Dr Priestley found†. The same philosopher also observed, that arterial blood acquired the colour of veinous blood when placed *in vacuo*‡. Consequently this alteration of colour is owing to some change which takes place in the blood itself, independent of any external agent.

The arterial blood becomes much more rapidly and deeply dark coloured when it is left in contact with hydrogen gas placed above it§. We must suppose therefore that the presence of this gas accelerates and increases the change, which would have taken place upon the blood without any external agent.

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* Davy's *Researches*, p. 380.

† Priestley, iii. 363.

‡ Ibid. and *Ann. de Chim.* ix. 269.

§ Fourcroy, Ibid vii. 149.

By rest,

9*th*, If arterial blood be left in contact with oxygen gas, it gradually assumes the same dark colour which it would have acquired *in vacuo*, or in contact with hydrogen; and after this change oxygen can no longer restore its scarlet colour *. Therefore it is only upon a part of the blood that the oxygen acts; and after this part has undergone the change which occasions the dark colour, the blood loses the power of being affected by oxygen.

And by oxy-muriatic acid.

10*th*, Mr Hassenfratz poured into veinous blood a quantity of oxy-muriatic acid; the blood was instantly decomposed, and assumed a deep and almost black colour. When he poured common muriatic acid into blood, the colour was not altered †. Now oxy-muriatic acid has the property of giving out its oxygen readily; consequently the black colour was owing to the instant combination of a part of the blood with oxygen.

Such are the phenomena produced upon the blood by the different gases out of the body; but the science is not far enough advanced at present to be able to explain them in a satisfactory manner. The obvious changes produced on the blood in the lungs by respiration, are the florid red colour and the disappearing of the chyle.

3. That carbonic acid is emitted from the lungs during expiration, has been fully ascertained; but whether it be formed in the lungs, according to the theory of Lavoisier, by the combination of the oxygen of the air with carbon emitted by the blood, or be emitted ready formed from the blood at the same time that the air is absorbed, is not so obvious; but the latter opi-

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* *Ann. de Chim.* ix. 268.

† Ibid.

nion is more probable, and indeed follows from the supposition that air is absorbed without decomposition.

4. It is much more reasonable to conclude that the watery vapour, which exhales from the lungs along with the air expired, has been emitted from the blood, or from the vessels of the lungs, than to suppose, with Lavoisier, that it is formed in the lungs by the combination of the oxygen of the air with hydrogen emitted from the blood.

Theory of respiration.

From the preceding enumeration of facts, we may conclude that the following changes are produced by respiration. The blood, as it passes through the lungs, absorbs a portion of air, and carries it along with it thro' the blood-vessels. During the circulation this air is gradually decomposed by the blood, its oxygen and part of its azot entering into new combinations, while at the same time a portion of azot, of carbonic acid, and water is evolved. When the blood returns to the ungs, it absorbs a new dose of air, and at the same ime lets go the azotic gas, carbonic acid gas, and watery vapour which had been formed during the circuation. The same changes are again repeated, and the ame substances emitted, every time the blood comes to he lungs.

Contributes to the formation of blood.

It is probable that, during a considerable part of the lay, there is a constant influx of chyle into the blood; nd we are certain that lymph is constantly flowing ino it. Now it appears, from the most accurate obserations hitherto made, that neither chyle nor lymph ontain fibrina, which forms a very conspicuous part f the blood. This fibrina is employed to supply the aste of the muscles; the most active parts of the body, nd therefore, in all probability, requiring the most frequent supply. Nor can it be doubted that it is employed for other useful purposes. The quantity of fibrina in the blood, then, must be constantly diminishing, and therefore new fibrina must be constantly formed. But the only substances out of which it can be formed are the chyle and lymph, neither of which contain it. There must therefore be a continual decomposition of the chyle and lymph going on in the blood-vessels, and a continual new formation of fibrina. Other substances also may be formed; but we are certain that this *must* be formed there, because it does not exist previously. Now, one great end of respiration must undoubtedly be to assist this decomposition of chyle and complete formation of blood.

It follows, from the experiments of Fourcroy formerly enumerated, that fibrina contains more azot, and less hydrogen and carbon, than any of the other ingredients of the blood, and consequently also than any of the ingredients of the chyle. In what manner the chyle, or a part of it, is converted into fibrina, it is impossible to say: we are not sufficiently acquainted with the subject to be able to explain the process. But we can see at least, that carbon and hydrogen must be abstracted from that part of the chyle which is to be converted into fibrina; and we know, that these substances are actually thrown out by respiration. We may conclude, then, that *one* use of the air absorbed is to abstract a quantity of carbon and hydrogen from a part of the chyle by compound affinity, in such proportions that the remainder becomes fibrina: therefore one end of respiration is to form fibrina. Doubtless the other ingredients of the blood are also new modified, though we know too little of the subject to throw any light upon it.

Occasions animal heat.

But the complete formation of blood is not the only advantage gained by respiration: the *temperature* of all animals depends upon it. It has been long known, that those animals which do not breathe have a temperature but very little superior to the medium in which they live. This is the case with fishes and many insects. Man, on the contrary, and quadrupeds which breathe, have a temperature considerably higher than the atmosphere: that of man is 98°. Birds, who breathe in proportion a still greater quantity of air than man, have a temperature equal to 103° or 104°. It has been proved, that the temperature of all animals is proporional to the quantity of air which they breathe in a gien time.

These facts are sufficient to demonstrate, that the eat of animals depends upon respiration. But it was ot till Dr Black's doctrine of latent heat became known o the world, that any explanation of the cause of the mperature of breathing animals was attempted. That lustrious philosopher, whose discoveries form the bais upon which all the scientific part of chemistry has een reared, saw at once the light which his doctrine of tent heat threw upon this part of physiology, and he pplied it very early to explain the temperature of aniials.

Dr Black's theory.

According to him, part of the latent heat of the air spired becomes sensible; and of course the temperare of the lungs, and the blood that passes through em, must be raised; and the blood, thus heated, comunicates its heat to the whole body. This opinion as ingenious, but it was liable to an unanswerable obction: for if it were true, the temperature of the body ight to be greatest in the lungs, and to diminish gradually as the distance from the lungs increases; which is not true. The theory, in consequence, was abandoned even by Dr Black himself; at least he made no attempt to support it.

Theory of Lavoisier and Crawford.

Lavoisier and Crawford, who considered all the changes operated by respiration as taking place in the lungs, accounted for the origin of the animal heat almost precisely in the same manner with Dr Black. According to them, the oxygen gas of the air combines in the lungs with the hydrogen and carbon emitted by the blood. During this combination, the oxygen gives out a great quantity of caloric, with which it had been combined; and this caloric is not only sufficient to support the temperature of the body, but also to carry off the new formed water in the state of vapour, and to raise considerably the temperature of the air inspired. According to these philosophers, then, the whole of the caloric which supports the temperature of the body is evolved in the lungs. Their theory accordingly was liable to the same objection with Dr Black's; but they obviated it in the following manner: Dr Crawford found, that the specific caloric of arterial blood was 1.0300, while that of veinous blood was only 0.8928. Hence he concluded, that the instant veinous blood is changed into arterial blood, its specific caloric increases; consequently it requires an additional quantity of caloric to keep its temperature as high as it had been while veinous blood. This addition is so great, that the whole new caloric evolved is employed: therefore the temperature of the lungs must necessarily remain the same as that of the rest of the body. During the circulation, arterial blood is gradually converted into veinous; consequently its specific caloric diminishes, nd it must give out heat. This is the reason that the emperature of the extreme parts of the body does not liminish.

This explanation is certainly ingenious; but it is not uite satisfactory; for the difference in the specific caloric, granting it to be accurate, is too small to account or the great quantity of heat which must be evolved. t is evident that it must fall to the ground altogether, rovided, as we have seen reason to suppose, that the arbonic acid gas and water are not formed in the lungs, ut during the circulation.

Heat evolved during the circulation.

Since the air enters the blood, and combines with it n the state of gas, it is evident that it will only part at rst with some of its caloric; and this portion is chiefly mployed in carrying off the carbonic acid gas, the azoic gas, and the water. For the reason that the carboic acid leaves the blood at the instant that the air ers it, seems to be this: The air combines with the lood, and part of its caloric unites at the same instant the carbonic acid, and converts it into gas: another ortion converts the water into vapour. The rest of e caloric is evolved during the circulation when the xygen of the air combines with hydrogen and carbon, nd forms water and carbonic acid gas. The quantity f caloric evolved in the lungs seems not only sufficient carry off the carbonic acid and water, which the diinution of the specific caloric (if it really take place) ust facilitate; but it seems also to raise the temperare of the blood a little higher than it was before. or Mr John Hunter constantly found, that the heat f the heart in animals was a degree higher than any her part of the body which he examined. Now this could scarcely happen, unless the temperature of the blood were somewhat raised during respiration.

Supports the circulation.

Thus we have seen two uses which respiration seems to serve. The first is the completion of blood by the formation of fibrina; the second is the maintaining of the temperature of the body at a particular standard, notwithstanding the heat which it is continually giving out to the colder surrounding bodies. But there is a third purpose, which explains why the animal is killed so suddenly when respiration is stopped. The circulation of the blood is absolutely necessary for the continuance of life. Now the blood is circulated in a great measure by the alternate contractions of the heart. It is necessary that the heart should contract regularly, otherwise the circulation could not go on. But the heart is stimulated to contract by the blood: and unless blood be made to undergo the change produced by respiration, it ceases almost instantaneously to stimulate. As the blood receives oxygen in the lungs, we may conclude that the presence of oxygen is necessary to its stimulating power*.

SECT. III.

OF THE ACTION OF THE KIDNEYS.

Thus we have reason to suppose, that chyle and lymph are converted into blood during the circulation; and that the oxygen gas supplied by respiration is one

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* Girtanner, *Jour. de Phys.* xxxix.

of the principal agents in this exchange. But besides the lungs and arteries, there is another organ, the sole use of which is also to produce some change or other in the blood, which renders it more complete, and more proper for the various purposes to which it is applied. This organ is the KIDNEY.

A very great proportion of blood passes through the kidneys; indeed we have every reason to conclude that the whole of the blood passes through them very frequently. These organs separate the urine from the blood, to be afterwards evacuated without being applied to any purpose useful to the animal.

Action of the kidneys necessary.

The kidneys are absolutely necessary for the continuance of the life of the animal; for it dies very speedily when they become by disease unfit to perform their functions: therefore the change which they produce in the blood is a change necessary for qualifying it to answer the purposes for which it is intended.

It changes the nature of the blood.

As the urine is immediately excreted, it is evident that the change which the kidneys perform is intended solely for the sake of the blood. It is not merely the abstraction of a quantity of water and of salts, accumulated in the blood, which the kidney performs. A chemical change is certainly produced, either upon the whole blood, or at least on some important part of it; for there are two substances found in the urine which do not exist in the blood. These two substances are urea and uric acid. They are formed, therefore, in the kidneys; and as they are thrown out, after being formed, without being applied to any useful purpose, they are certainly not formed in the kidneys for their own sake. Some part of the blood, then, must be decomposed in the kidney, and a new substance, or new substances, must be formed; and the urea and uric acid must be formed at the same time, in consequence of the combined action of the affinities which produce the change on the blood; and being useless, they are thrown out together with a quantity of water and salts, which, in all probability, were useful in bringing about the changes which take place in the arteries and in the kidneys, but which are no longer of any service after these changes are brought about.

The changes operated upon the blood in the kidneys are at present altogether unknown; but they must be important. Provided the method of analysing animal substances were so far perfected as to admit of accurate conclusions, considerable light might be thrown upon this subject, by analysing with care a portion of blood from the emulgent vein and artery separately, and ascertaining precisely in what particulars they differ from each other.

SECT. IV.

OF PERSPIRATION.

Thus we have seen that the principal changes which the blood undergoes, as far at least as we are at present acquainted with them, take place in the lungs, in the kidneys, and in the arteries. In the lungs, a quantity of water and carbonic acid gas is emitted from the blood; and in the kidney, the urine is formed and separated from it. There seems also to be something thrown out from the blood during its circulation in the arteries, at least through those vessels which are near the surface of the body; for it is a fact, that certain substances are constantly emitted from the skins of animals. These substances are known in general by the name of *perspirable matter*, or *perspiration*. They have a great resemblance to what is emitted in the lungs; which renders it probable that both excretions are owing to the same cause; namely, to the decomposition produced in the blood by the effects of respiration.

Quantity perspired.

Many experiments have been made to ascertain the quantity of matter perspired through the skin. For the first set, and not the least remarkable, we are indebted to Sanctorius; who continued them for no less than 30 years. He ascertained his own weight and the weight of his food; and whatever weight he lost over and above that of his excrements, he ascribed to perspiration. A similar set of experiments was afterwards made in France by Dodart; in England by Keil; in Ireland by Bryan Robertson and Rye; and in Carolina by Lining. The result of all these experiments has been collected by Haller; but it gives us no precise estimate of the amount of the transpiration, since these philosophers have not distinguished between what is lost by the skin and by the lungs. Lavoisier and Seguin alone have attempted to ascertain the amount of the matter perspired through the skin. A bag composed of varnished silk, and perfectly air-tight, was procured, within which Seguin, who was usually the subject of experiment, was enclosed, and the bag was closed exactly over his head. There was a slit in the bag opposite to his mouth, and the edges of this slit were accurately cemented round the mouth by means of a mixture of turpentine and pitch. Thus every thing emitted by the body was retained in the bag, except what made its escape from the lungs by respiration. By weighing himself in a delicate balance at the commencement of the experiment, and again after he had continued for some time in the bag, the quantity of matter carried off by respiration was ascertained. By weighing himself without this varnished covering, and repeating the operation after the same interval of time had elapsed as in the former experiment, he ascertained the loss of weight occasioned by perspiration and respiration. By subtracting from this sum the loss of weight indicated by the first experiment, he obtained the quantity of matter which made its escape by perspiration in a given time. The following facts were ascertained by these experiments:

1. The maximum of matter perspired in a minute amounted to 26.25 grains troy; the minimum to 9 grains: which gives 17.63 grains at a medium in the minute, or 52.89 ounces in the 24 hours. This quantity differs less than might have been expected from the result of former experiments made by Dodart, Keil, Rye, &c.

2. The quantity perspired is increased by drink, but not by solid food.

3. Perspiration is at its minimum immediately after a repast. It reaches its maximum during digestion *.

The quantity of matter perspired differs very considerably according to circumstances. It has been shewn to be greatest in hot weather, and in hot climates, and after great exercise; and its relation to the quantity of urine has been long known. When the matter per-

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* Fourcroy, ix. 198.

perspired is great, the quantity of urine is small, and *vice versa*.

Substances perspired.

To ascertain the substances thus emitted by perspiration is a difficult task, because it passes off invisibly, and in small quantities at a time. It has, notwithstanding, been ascertained that water, carbon, and an oily matter, are emitted; and that an acid, supposed to be the phosphoric, phosphat of lime, and even urea, are sometimes emitted through the skin.

1. Water.

1. The most accurate experiments on this matter that have been made are those of Mr Cruickshank. He put his hand into a glass vessel, and luted its mouth at his wrist by means of a bladder. The interior surface of the vessel became gradually dim, and drops of water trickled down. By keeping his hand in this manner for an hour, he collected 30 grains of a liquid, which possessed all the properties of pure water*. On repeating the same experiment at nine in the evening (thermometer 62°), he collected only 12 grains. The mean of these is 21 grains. But as the hand is more exposed than the trunk of the body, it is reasonable to suppose that the perspiration from it is greater than that from the hand. Let us therefore take 30 grains per hour as the mean; and let us suppose, with Mr Cruickshank, that the hand is $\frac{1}{60}$th of the surface of the body. The perspiration in an hour would amount to 1800 grains, and in 24 hours to 43200 grains, or 7 pounds 6 ounces troy. This is almost double of the quantity ascertained by Lavoisier and Seguin. Hence we may conclude that more matter is perspired through the hand than the other parts of the body, provided Mr

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* *On Insensible Perspiration*, 68.

Cruickshank's estimate of the ratio between the surface of the hand and body be not erroneous.

He repeated the experiment again after hard exercise, and collected in an hour 48 grains of water*. He found also, that this aqueous vapour pervaded his stocking without difficulty; and that it made its way through a shamoy leather glove, and even through a leather boot, though in much smaller quantity than when the leg wanted that covering†.

It is not difficult to see why the quantity of watery vapour diminishes with cold. When the surface of the body is exposed to a cold temperature, the capacity of the cutaneous vessels diminishes, and consequently the quantity which flows through them must decrease.

When the temperature, on the other hand, is much increased, either by being exposed to a hot atmosphere, or by violent exercise, the perspired vapour not only increases in quantity, but even appears in a liquid form. This is known by the name of *sweat*. In what manner sweat is produced, is not at present known; but we can see a very important service which it performs to the animal. No sooner is it thrown upon the surface of the skin than it begins to evaporate. But the change into vapour requires heat; accordingly a quantity of heat is absorbed, and the temperature of the animal is lowered. This is the reason that animals can endure to remain for some time in a much higher temperature without injury than could have been supposed.

Sweat.

The experiments of Tillet, and the still more decisive experiments of Fordyce and his associates, are well known. These gentlemen remained a considerable time in a temperature exceeding the boiling point of water.

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[*] *On Insensible Perspiration*, p. 70.

[†] Ibid. p. 82.

Chap. III.

2. Carbon.

2. Besides water, it cannot be doubted that *carbon* is also emitted from the skin; but in what state, the experiments hitherto made do not enable us to decide. Mr Cruikshank found that the air of the glass vessel in which his hand and foot had been confined for an hour contained carbonic acid gas; for a candle burned dimly in it, and it rendered lime-water turbid*. And Mr Jurine found that air which had remained for some time in contact with the skin consisted almost entirely of carbonic acid gas †. The same conclusion may be drawn from the experiments of Ingenhousz and Milly ‡.

Now it is evident, that the carbonic acid gas which appeared during Mr Cruickshank's experiment did not previously exist in the glass vessel; consequently it must have either been transmitted ready formed through the skin, or formed during the experiment by the absorption of oxygen gas, and the consequent emission of carbonic acid gas. The experiments of Mr Jurine do not allow us to suppose the first of these to be true; for he found that the quantity of air allowed to remain in contact with the skin did not increase. Consequently the appearance of the carbonic acid gas must be owing, either to the emission of carbon, which forms carbonic acid gas by combining with the oxygen gas of the air, or to the absorption of oxygen gas, and the subsequent emission of carbonic acid gas; precisely in the same manner, and for the same reason, that these substances are emitted by the lungs. The last is the more probable opinion; but the experiments hitherto made do not enable us to decide.

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* *On Insensible Perspiration*, p. 70. and 81.

† *Encyc. Meth. Med.* i. 515.

‡ Ibid. p. 511.

3. An oily matter.

3. Besides water and carbon, or carbonic acid gas, the skin emits also a particular odorous substance. That every animal has a peculiar smell, is well known: the dog can discover his master, and even trace him to a distance by the scent. A dog, chained some hours after his master had set out on a journey of some hundred miles, followed his footsteps by the smell, and found him on the third day in the midst of a crowd*. But it is needless to multiply instances of this fact; they are too well known to every one. Now this smell must be owing to some peculiar matter which is constantly emitted; and this matter must differ somewhat either in quantity or some other property, as we see that the dog easily distinguishes the individual by means of it. Mr Cruickshank has made it probable that this matter is an oily substance; or at least that there is an oily substance emitted by the skin. He wore repeatedly, night and day for a month, the same vest of fleecy hosiery during the hottest part of the summer. At the end of this time he always found an oily substance accumulated in considerable masses on the nap of the inner surface of the vest, in the form of black tears. When rubbed on paper, it makes it transparent, and hardens on it like grease. It burns with a white flame, and leaves behind it a charry residuum†.

4. An acid, and

Phosphat of lime and urea in quadrupeds.

4. Berthollet has observed the perspiration acid; and he has concluded that the acid which is present is the phosphoric: but that has not been proved. Fourcroy and Vauquelin have ascertained that the scurf which collects upon the skins of horses consists chiefly of phosphat of lime, and urea is even sometimes mixed with

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[*] Cruickshank on *Insensible Perspiration*, p. 93.

[†] Ibid. p. 92.

it. It is well known that the sweat has a salt taste; but hitherto it has not been analysed, though it probably differs from the transpiration.

It has been supposed that the skin has the property of *absorbing moisture* from the air; but this opinion has not been confirmed by experiments, but rather the contrary.

Whether the skin absorbs moisture.

The chief arguments in favour of the absorption of the skin, have been drawn from the quantity of moisture discharged by urine being, in some cases, not only greater than the whole drink of the patient, but even than the whole of his drink and food. But it ought to be remembered that, in diabetes, the disease here alluded to, the weight of the body is continually diminishing, and therefore part of it must be constantly thrown off. Besides, it is scarcely possible in that disease to get an accurate account of the food swallowed by the patients; and in those cases where very accurate accounts have been kept, and where deception was not so much practised, the urine was found not to exceed the quantity of drink *. In a case of diabetes, related with much accuracy by Dr Gerard, the patient was bathed regularly during the early part of the disease in warm water, and afterwards in cold water: he was weighed before and after bathing, and no sensible difference was ever found in his weight †. Consequently, in that case, the quantity absorbed, if any, must have been very small.

It is well known that thirst is much alleviated by cold bathing. By this plan, Captain Bligh kept his

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* See Rollo on *Diabetes*.

† Ibid. ii. 73.

men cool and in good health during their very extraordinary voyage across the South Sea. This has been considered as owing to the absorption of water by the skin. But Dr Currie had a patient who was wasting fast for want of nourishment, a tumor in the œsophagus preventing the possibility of taking food, and whose thirst was always alleviated by bathing; yet no sensible increase of weight, but rather the contrary, was perceived after bathing. It does not appear, then, that in either of these cases water was absorbed.

Farther, Seguin has shewn that the skin does not absorb water during bathing, by a still more complete experiment: He dissolved some mercurial salt in water, and found that the mercury produced no effect upon a person that bathed in the water, provided no part of the cuticle was injured; but upon rubbing off a portion of the cuticle, the mercurial solution was absorbed, and the effects of the mercury became evident upon the body. Hence it follows irresistibly, that water, at least in the state of *water*, is not absorbed by the skin when the body is plunged into it unless the cuticle be first removed.

Whether it absorbs other substances.

This may perhaps be considered as a complete proof that no such thing as absorption is performed by the skin; and that therefore the appearance of carbonic acid gas, which takes place when air is confined around the skin, must be owing to the emission of carbon. But it ought to be considered, that although the skin cannot absorb water, this is no proof that it cannot absorb other substances; particularly that it cannot absorb oxygen gas, which is very different from water. It is well known that water will not pass through bladders, at least for some time: yet Dr Priestley found that einous blood acquired the colour of arterial blood from xygen gas, as readily when these substances were se- arated by a bladder as when they were in actual con- act. He found, too, that when gases were confined in ladders, they gradually lost their properties. It is lear from these facts, that oxygen gas can pervade ladders; and if it can pervade them, why may it not so pervade the cuticle? Nay, farther, we know from e experiments of Cruikshank, that the vapour per- ired passes through leather, even when prepared so to keep out moisture, at least for a certain time. It possible, then, that water, when in the state of va- ur, or when dissolved in air, may be absorbed, al- ough water, while in the state of water, may be in- pable of pervading the cuticle. The experiments, erefore, which have hitherto been made upon the ab- rption of the skin, are insufficient to prove that air d vapour cannot pervade the cuticle, provided there any facts to render the contrary supposition pro- ble.

Now that there are such facts cannot be denied. I ll not indeed produce the experiment of Van Mons a fact of that kind, because it is liable to objections, l at best is very indecisive. Having a patient under care who, from a wound in the throat, was inca- le for several days of taking any nourishment, he t him alive during that time, by applying to the n in different parts of the body, several times a day, onge dipt in wine or strong soup *. A fact men- ned by Dr Watson is much more important, and ch more decisive. A lad at Newmarket, who had

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* *Phil. Mag.* vi. 95.

Book V.

been almost starved in order to bring him down to such a weight as would qualify him for running a horse race, was weighed in the morning of the race day; he was weighed again just before the race began, and was found to have gained 30 ounces of weight since the morning; yet in the interval he had only taken a single glass of wine. Here absorption must have taken place, either by the skin, or lungs, or both. The difficulties in either case are the same; and whatever renders absorption by one probable, will equally strengthen the probability that absorption takes place by the other*.

SECT. V.

OF ASSIMILATION.

Blood answers two purposes. 1. Supplies the waste of the system.

We have now seen the progress of digestion, and the formation of blood, as far at least as we are acquainted with it. But to what purposes is this blood employed, which is formed with so much care, and for the formation of which so great an apparatus has been provided? It answers two purposes. The parts of which the body is composed, bones, muscles, ligaments, membranes, &c. are continually changing. In youth they are increasing

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[*] The Abbé Fontana also found that, after walking in moist air for an hour or two, he returned home some ounces heavier than he went out, notwithstanding he had suffered considerable evacuation from a brisk purge purposely taken for the experiment. This increase, indeed, might be partly accounted for by the absorption of moisture by his clothes.

in size and strength, and in mature age they are continually acting, and consequently continually liable to waste and decay. They are often exposed to accidents, which render them unfit for performing their various functions; and even when no such accident happens, it seems necessary for the health of the system that they should be every now and then renewed. Materials therefore must be provided for repairing, increasing, or renewing all the various organs of the body. Phosphat of lime and gelatine for the bones, fibrina for the muscles, albumen for the cartilages and membranes, &c. Accordingly all these substances are laid up in the blood; and they are drawn from that fluid as from a storehouse whenever they are required. The process by which the different ingredients of the blood are made part of the various organs of the body is called ASSIMILATION.

Assimilation.

Over the nature of assimilation the thickest darkness still hangs; there is no key to explain it, nothing to lead us to the knowledge of the instruments employed. Facts, however, have been accumulated in sufficient numbers to put the existence of the process beyond the reach of doubt. The healing, indeed, of every fractured bone, and every wound of the body, is a proof of its existence, and an instance of its action.

Every assimilating organ produces a specific change,

Every organ employed in assimilation has a peculiar office; and it always performs this office whenever it has materials to act upon, even when the performance of it is contrary to the interest of the animal. Thus the stomach always converts food into chyme, even when the food is of such a nature that the process of digestion will be retarded rather than promoted by the change. If warm milk, for instance, or warm blood, be thrown into the stomach, they are always decomposed by that organ, and converted into chyme; yet these substances are much more nearly assimilated to the animal before the action of the stomach than after it. The same thing happens when we eat animal food.

And no other.

On the other hand, a substance introduced into an organ employed in assimilation, if it has undergone precisely the change which that organ is fitted to produce, is not acted upon by that organ, but passed on unaltered to the next assimilating organ. Thus it is the office of the intestines to convert chyme into chyle. Accordingly, whenever chyme is introduced into the intestines, they perform their office, and produce the usual change; but if chyle itself be introduced into the intestines, it is absorbed by the lacteals without alteration. The experiment, indeed, has not been tried with true chyle, because it is scarce possible to procure it in sufficient quantity; but when milk, which resembles chyle pretty accurately, is thrown into the jejunum, it is absorbed unchanged by the lacteals *.

Again, the office of the blood-vessels, as assimilating organs, is to convert chyle into blood. Chyle, accordingly, cannot be introduced into the arteries without undergoing that change; but *blood* may be introduced from another animal without any injury, and consequently without undergoing any change. This experiment was first made by Lower, and it has since been very often repeated.

Also, if a piece of fresh muscular flesh be applied to the muscle of an animal, they adhere and incorporate without any change, as has been sufficiently established

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* Fordyce on *Digestion*, p. 189.

by the experiments of Mr J. Hunter. And Buvina has ascertained, that fresh bone may, in the same manner, be engrafted on the bones of animals of the same or of different species *.

Foreign substances may be incorporated with the body.

In short, it seems to hold, at least as far as experiments have hitherto been made, that foreign substances may be incorporated with those of the body, provided they be precisely of the same kind with those to which they are added, whether fluid or solid. Thus chyle may be mixed with chyle, blood with blood, muscle with muscle, and bone with bone. The experiment has not been extended to the other animal substances, the nerves, for instance; but it is extremely probable that it would hold with respect to them also.

On the other hand, when substances are introduced into any part of the body which are not the same with that part, nor the same with the substance upon which that part acts, provided they cannot be thrown out readily, they destroy the part, and perhaps even the animal. Thus foreign substances introduced into the blood very soon prove fatal; and introduced into wounds of the flesh or bones, they prevent these parts from healing.

Powers of the assimilating organs limited.

Although the different assimilating organs have the power of changing certain substances into others, and of throwing out the useless ingredients, yet this power is not absolute, even when the substances on which they act are proper for undergoing the change which the organs produce. Thus the stomach converts food into chyme, the intestines chyme into chyle, and the substances which have not been converted into chyle are

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* *Phil. Mag.* vi. 308.

thrown out of the body. If there happen to be present in the stomach and intestines any substance which, though incapable of undergoing these changes, at least by the action of the stomach and intestines, yet has a strong affinity, either for the whole chyme and chyle, or for some particular part of it, and no affinity for the substances which are thrown out, that substance passes along with the chyle, and in many cases continues to remain chemically combined with the substance to which it is united in the stomach, even after that substance has been completely assimilated, and made a part of the body of the animal. Thus there is a strong affinity between the colouring matter of madder and phosphat of lime. Accordingly, when madder is taken into the stomach, it combines with the phosphat of lime of the food, passes with it through the lacteals and blood vessels, and is deposited with it in the bones, as was proved by the experiments of Duhamel. In the same manner musk, indigo, &c. when taken into the stomach, make their way into many of the secretions.

These facts shew us that assimilation is a chemical process from beginning to end; that all the changes are produced according to the laws of chemistry; and that we can even derange the regularity of the process by introducing substances whose mutual affinities are too strong for the organs to overcome.

Assimilation a chemical process;

It cannot be denied, then, that the assimilation of food consists merely in a certain number of chemical decompositions which that food undergoes, and the consequent formation of certain new compounds. But are the *agents* employed in assimilation merely chemical agents? We cannot produce any thing like these changes on the food out of the body, and therefore we must allow that they are the consequence of the action of the animal organs. But this action, it may be said, is merely the secretion of particular juices, which have the property of inducing the wished-for change upon the food: and this very change would be produced out of the body, provided we could procure these substances, and apply them in proper quantity to the food. If this supposition be true, the specific action of the vessels consists in the secretion of certain substances; consequently the cause of this secretion is the *real* agent in assimilation. Now, can the *cause* of this secretion be shewn to be merely a chemical agent? Certainly not. For in the stomach, where only this secretion can be shewn to exist, it is not always the same, but varies according to circumstances. Thus eagles at first cannot digest grain, but they may be brought to do it by persisting in making them use it as food. On the contrary, a lamb cannot at first digest animal food, but habit will also give it this power. In this case, it is evident that the gastric juice changes according to circumstances.

But the agent not chemical.

The presence of some agent, different from a mere chemical power, will be still more evident, if we consider the immunity of the stomach of the living animal during the process of digestion. The stomach of animals is as fit for food as any other substance. The gastric juice, therefore, must have the same power of acting on it, and of decomposing it, that it has of acting on other substances; yet it is well known that the stomach is not affected by digestion while the animal retains life; though, as Mr Hunter ascertained, the very gastric juice which the living stomach secretes often dissolves the stomach itself after death. Now what is the power which prevents the gastric juice from acting on the stomach during life? Certainly neither a chemical nor mechanical agent, for these agents must still retain the same power after death. We must, then, of necessity, conclude, that there exists in the animal an agent very different from chemical and mechanical powers, since it controuls these powers according to its pleasure. These powers therefore in the living body are merely the servants of this superior agent, which directs them so as to accomplish always one particular end. This agent seems to regulate the chemical powers, chiefly by bringing only certain substances together which are to be decomposed, and by keeping at a distance those substances which would interfere with, or diminish, or spoil the product, or injure the organ. And we see that this separation is always attended to even when the substances are apparently mixed together. For the very same products are not obtained which would be obtained by mixing the same substances together out of the body that are produced by mixing them in the body; consequently all the substances are not left at full liberty to obey the laws of their mutual affinities. The superior agent, however, is not able to exercise an unlimited authority over the chemical powers; sometimes they are too strong for it: some substances accordingly, as madder, make their way into the system; while others, as arsenic, decompose and destroy the organs of the body themselves.

But it is not in digestion alone that this superior agent makes the most wonderful display of its power; it is in the last part of assimilation that our admiration is most powerfully excited. How comes it that the precise substances wanted are always carried to every organ of the body? How comes it that fibrina is always regularly deposited in the muscles, and phosphat of lime in the bones? And what is still more unaccountable, how comes it that prodigious quantities of some one particular substance are formed and carried to a particular place in order to supply new wants which did not before exist? A bone, for example, becomes diseased and unfit for the use of the animal; a new bone therefore is formed in its place, and the old one is carried off by the absorbents. In order to form this new bone, large quantities of phosphat of lime are deposited in a place where the same quantity was not before necessary. Now, who informs this agent that an unusual quantity of phosphat of lime is necessary, and that it must be carried to that particular place? Or granting, as is most probable, that the phosphat of lime of the old bone is partly employed for this purpose, who taught this agent that the old bone must be carried off, new modelled, and deposited, and assimilated anew? The same wonders take place during the healing of every wound, and the renewing of every diseased part.

But neither in this case is the power of this agent over the chemical agents, which are employed, absolute. We may prevent a fractured bone from healing by giving the partient large quantities of acids. And unless the materials for the new-wanted substances be supplied by the food, they cannot in many cases be formed at all. Thus the canary bird cannot complete her eggs unless she be furnished with lime.

Nature of this agent,

As this agent which characterizes living bodies does not appear to act according to the principles of chemistry, any enquiry into its nature would be foreign to the subject of this Work. Physiologists have given it the name of the *living* or *animal* principle; and to them I beg leave to refer the reader.

2. Blood furnishes the materials of secretion.

Besides the different organs of the body, the blood is also employed in forming all the different secretions which are necessary for the purposes of the animal economy. These have been enumerated in the last Chapter. The process is similar to that of assimilation, and undoubtedly the agents in both cases are the same; but we are equally ignorant of the precise manner in which secretion is performed as we are of assimilation.

Animals decay and die.

After these functions have gone on for a certain time, which is longer or shorter according to the nature of the animal, the body gradually decays, at last all its functions cease completely, and the animal dies. The cause of this must appear very extraordinary, when we consider the power which the animal has of renewing decayed parts; for it cannot be doubted that death proceeds, in most cases at least, from the body becoming incapable of performing its function. But if we consider that this power is limited, and that it must cease altogether when those parts of the system begin to decay which are employed in preparing materials for future assimilation, our surprise will, in some measure, cease. It is in these parts, in the organs of digestion and assimilation, accordingly, that this decay usually proves fatal. The decay in other parts destroys life only when the waste is so rapid that it does not admit of repair.

What the reason is that the decay of the organs causes death, or, which is the same thing, causes the living principle either to cease to act, or to leave the body altogether, it is perfectly impossible to say, because we know too little of the nature of the living principle, and of the manner in which it is connected with the body. The last is evidently above the human understanding; but many of the properties of the living principle have been discovered: and were the facts already known properly arranged, and such general conclusions drawn from them as their connection with each other fully warrant, a degree of light would be thrown upon the animal economy, which those who have not attended to the subject are not aware of.

No sooner is the animal dead, than the chemical and mechanical agents, which were formerly servants, usurp the supreme power, and soon decompose and destroy that very body which had been in a great measure reared by their means. But the changes which take place upon animal bodies after death, are too important to be passed over slightly. They shall therefore form the subject of the next Chapter.

CHAP. IV.

OF THE DECOMPOSITION OF ANIMAL BODIES.

THE rapidity with which animal bodies undergo decomposition, and the disgusting fetor which accompanies this decomposition, have long been considered as some of their most striking peculiarities. This spontaneous destruction is denominated *putrefaction*. Considerable attention has been paid to it by chemists. Becher and Stahl have described with fidelity the phenomena with which it is attended, and the circumstances necessary for it taking place. Several curious remarks on it were made by Boyle and Beale*. To Sir John Pringle we are indebted for some important experiments on the method of retarding putrefaction†; neither are the experiments of Dr Macbride less valuable, though the consequences which he drew from them were erroneous. We are cndebted also to Crell and Priestley for many valuable facts; and to Berthollet and Lavoisier for the first attempts to determine the real changes which take place, and the manner in which the new products which appear during putrefaction are formed. But notwithstanding the labours of these philosophers, and of many others, much is still wanting to enable us to trace the complicated changes which take place during putrefaction, and to account for them in a satisfactory manner.

Conditions requisite for putrefaction.

It has been ascertained long ago, that putrefaction never takes place in those animal substances which contain only two or three ingredients, such as oils, resins, sugar; they must always be more complicated in their texture; and perhaps in all cases a mixture of two or more compound bodies is necessary for speedy decompostion. But however complicated the animal substance may be, it does not putrefy unless moisture be present; for dry animal substances are not susceptible of alteration. A certain degree of heat is also necessary. Animal bodies may be kept without decomposing for any length of time at the freezing temperature. In general the higher the temperature the more rapid is the putrefaction, provided the heat be not great enough

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* *Phil. Trans.* iv. 1135.

† Ibid. xlvi. 480. &c.

to reduce the animal body to dryness. It has been observed, too, that putrefaction advances with more rapidity in the open air; but exposure to the air is not necessary, though it modifies the decomposition.

Putrefaction in the air.

When these conditions are observed, and dead animal matter is left to itself, its colour becomes gradually paler, and its consistence diminishes; if it be a solid part, such as flesh, it softens, and a serous matter sweats out, whose colour quickly changes; the texture of the part becomes relaxed, and its organization destroyed; it acquires a disagreeable smell; the substance gradually sinks down, and is diminished in bulk; its smell becomes stronger and ammoniacal. If the subject be contained in a close vessel, the progress of putrefaction, at this stage, seems to slacken; no other smell but that of a pungent alkali is perceived; the matter effervesces with acids, and converts syrup of violets to a green. But if the communication with the air be admitted, the urinous exhalation is dissipated, and a peculiar putrid smell is spread around with a kind of impetuosity; a smell of the most insupportable kind, which lasts a long time, and pervades every place, affecting the bodies of living animals after the manner of a ferment, capable of altering the fluids: this smell is corrected, and as it were confined by ammonia. When the latter is volatilized, the putrefactive process becomes active a second time, and the substance suddenly swells up, becomes filled with bubbles of air, and soon after subsides again. Its colour changes, the fibrous texture of the flesh being then scarcely distinguishable; and the whole is changed into a soft brown, or greenish matter, of the consistence of a poultice, whose smell is faint, nauseous, and very active on the bodies of animals. The odorant principle gradually loses its force; the fluid portion of the flesh assumes a kind of consistence, its colour becomes deeper, and it is finally reduced into a friable matter, rather deliquescent; which being rubbed between the fingers, breaks into a coarse powder like earth. This is the last state observed in the putrefaction of animal substances; they do not arrive at this term but at the end of a considerable time *.

Products.

During this decomposition a variety of gaseous bodies are emitted: these vary according to the substance exposed to putrefaction; but they consist chiefly of hydrogen gas, holding sulphur, phosphorus, and carbon in solution; of ammonia, water, and carbonic acid, and perhaps also of azotic gas. Nitric acid seems in some cases to be formed and emitted. The earthy-like residuum, which remains after the decomposition is completed, consists of the fixed parts of the animal substance, mixed with charcoal, oil, and ammonia. Thus it appears that putrefaction consists in a total decomposition of the animal body; the elements of which combine together two and two, and thus form a new set of less complicated bodies. But any attempt to explain the manner in which these changes take place, would be exceedingly imperfect indeed; not only because we are ignorant of the strength of the affinities of the different elementary parts of animal bodies for each other, but because we do not even know the manner in which these elements are combined, and consequently we cannot know by what particular forces these compounds are destroyed.

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* Fourcroy.

Putrefaction under ground.

In carcases buried in the earth, putrefaction takes place much more slowly; but it is scarcely possible to observe its progress with accuracy. The abdomen is gradually dilated with elastic fluids which make their appearance in it, and at last it bursts and discharges a horribly fetid and noxious gas; at the same time a dark coloured liquid flows out. If the earth be very dry, and the heat considerable, the moisture is often absorbed so rapidly, that the carcase, instead of putrefying, dries, and is transformed into what is called a *mummy*.

Putrefaction of accumulated animal matter.

Such are the phenomena when dead bodies are left to putrefy separately: but when great numbers of carcases are crowded together in one place, and are so abundant as to exclude the action of external air and other foreign agents, their decomposition is entirely the consequence of the reciprocal action of their ingredients themselves upon each other, and the result is very different. The body is not entirely dissipated or reduced to mould, but all the soft parts are found diminished remarkably in size, and converted into a peculiar *saponaceous matter*. This singular change was first accurately observed in the year 1786.

Converted into a saponaceous matter.

The burial ground of the Innocents in Paris having become noxious to those who lived in its neighbourhood, on account of the disagreeable and hurtful odour which it exhaled, it was found necessary to remove the carcases to another place. It had been usual to dig very large pits in that burial ground, and to fill them with the carcases of the poorer sort of people, each in its proper bier; and when they were quite full, to cover them with about a foot deep of earth, and to dig another similar pit, and fill it in the same manner. Each pit held between 1000 and 1500 dead bodies. It was in removing the bodies from these pits that this saponaceous substance was found. The grave-diggers had ascertained, by long experience, that about thirty years were required before all the bodies had undergone this change in its full extent *. Every part of the body acquired the properties of this substance. The intestines and viscera of the thorax had completely disappeared; but what is singular enough, the brain had lost but little of its size or appearance, though it was also converted into the same substance.

Its properties.

This saponaceous matter was of a white colour, soft and unctuous to the touch, and melted, when heated, like tallow. It exhibited all the properties of a *soap*, containing, however, an excess of fatty matter. Fourcroy, who analysed it, found that it was composed of a fatty matter combined with ammonia, and that it contained also some phosphat of lime and ammonia. Diluted acids decomposed it, and separated the fatty matter: alkalies and lime, on the other hand, drove off the ammonia. When exposed to the air, it gradually lost its white colour; the ammonia, in a great measure, evaporated; and what remained had something of the appearance of wax. It absorbed water with great avidity, and did not part with it readily. Its white colour was owing to the presence of that liquid. The oily matter, when separated by means of a diluted acid, was concrete, and of a white colour, owing to the mixture of a quantity of water. When dried, it acquires a greyish-brown colour, a lamellar and crystalline texture, like that of spermaceti; but if it has been rapidly

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* Fourcroy, *Ann. de Chim.* v. 154.

dried, it assumes the appearance of wax. It melts when heated to 126°; when properly purified, by passing it through a linen cloth while fluid, it has scarcely any smell. Alcohol does not act apon it while cold, but at the temperature of 120° it dissolves it: when the solution cools, the fatty matter precipitates, and forms a gritty mass. With alkalies it forms a soap; and when set on fire it burns precisely like oil or fat, only that it exhales a more unpleasant odour*.

Mr Smith Gibbes found the same substance in the pit into which animal matters are thrown at Oxford after dissection. A small stream of water constantly passes through this pit; a circumstance which induced him to try whether animal muscle exposed to the action of a running stream underwent the same change. The experiment succeeded completely: he attempted, in consequence, to render this substance, to which he gave the name of *spermaceti*, useful in those manufactures which require tallow: but the fetid odour which it constantly exhales was an unsurmountable objection†. Attempts were indeed made to get over it; and a manufacture of Mr Smith Gibbes's spermaceti has even been established at Bristol.

Substances which retard putrefaction.

Many attempts have been made to retard the destructive progress of putrefaction, in order to preserve animal bodies either as food or for other useful purposes; and several methods have been ascertained which prevent it from operating for a considerable time.

1. The freezing temperature is a complete preserva-

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* Fourcroy, *Ann. de Chim.* viii. 17.

† *Phil. Trans.* 1794 and 1795.

tive from putrefaction, as long as the animal substance is exposed to it. Hence the common practice of keeping meat in snow in the frozen climates of the north; and of packing fish in ice, and sending them in that state from Scotland to the London market.

2. Almost all bodies which have a strong affinity for water retard putrefaction for a longer or shorter time, doubtless by depriving the animal substances of their water, or preventing that liquid from acting upon these bodies in its usual manner. In this way the acids, sugar, alcohol, &c. seem to prevent or retard putrefaction.

3. It is well known that common salt is a powerful antiseptic. Hence the practice of salting meat, and the length of time which meat that has undergone this operation may be kept. Several other salts, especially nitre, possess the same property. In what manner these bodies act has not been ascertained; but they undoubtedly produce some chemical change upon the meat; for they alter its taste, its colour, and other sensible properties.

4. Many aromatic bodies, such as camphor, resins, volatile oils, bitumens, and other similar bodies, act with considerable efficacy in preserving animal bodies from putrefaction. Hence their utility in embalming. In what the action of these substances consists has not been ascertained. Part of their efficacy is doubtless owing to the rapidity with which the animal substances to which they are applied lose their moisture; and something may be ascribed likewise to their odour, which keeps insects at a distance, and thus prevents the lodging of excrementitious matter, which always acts powerfully as a putrefactive ferment.

APPENDIX.

In a science of so extensive a nature as CHEMISTRY, which is cultivated in so many different countries, and by so numerous a body of eminent philosophers, new facts must be continually expected; and our opinions and theories, which serve merely as stepping-stones to conduct us to truth, must, in consequence, be frequently altered and modified anew. Since the commencement of this Work nearly eight months have elapsed, and during that time many important additions have been made to our knowledge. Such of these discoveries as could be introduced into the preceding Work have been already explained; those which were not published soon enough to be inserted in their proper place, or which did not come soon enough to hand, I think it necessary to enumerate in an Appendix, that the reader may have as complete a view as possible of the present state of the science. In this enumeration I shall follow exactly the order of arrangement which has been adopted in the Work itself.

Book I.

Part I.—Book I.—Chap. I. Of Oxygen. Vol. I. p. 25.

I have exhibited a Table of the affinities of oxygen for different bodies; mentioning in a note that the affinity of several of the metals for that substance was unknown. Mr Vauquelin has lately published a table of the affinity of the metals for oxygen*, arranging them according to the difficulty with which the metallic oxides are decomposed by heat. Though this mode of estimating the strength of affinity is liable to objections, I shall here insert the Table, because it is useful.

Affinities of oxygen.

Oxygen.

Titanium,
Manganese,
Zinc,
Iron,
Tin,
Uranium,
Molybdenum,
Tungsten,
Cobalt,
Antimony,
Nickel,
Arsenic,
Chromum,
Bismuth,
Lead,
Copper,
Tellurium,

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* Patrin's *Mineralogy*, v. 189.

Platinum,
Mercury,
Silver,
Gold.

Chap. III. Of Metals. Vol. I. p. 75.

Three important additions have been made to our knowledge since this Chapter was written. 1. An analysis of several metallic oxides by Proust, which has rectified several mistaken opinions to which that ingenious chemist had himself given occasion. 2. Additional experiments on nickel by Mr Chenevix, which re-establish an opinion that had been rejected in consequence of the experiments of several eminent German and French chemists. 3. The discovery of a new metal by Mr Hatchett. Of each of these particulars I shall give an account.

I. Of Metallic Sulphurets.

Cinnabar.

1. Cinnabar has hitherto been supposed a compound of the red oxide of mercury and sulphur; but Mr Proust has ascertained that it is composed of

85 mercury
15 sulphur

100

For it yields 15 parts of sulphur to antimony, and 85 of mercury are separated. When a mixture of muriat of mercury and sulphur is distilled, the product is cinnabar and oxy-muriat of mercury *. When mercury

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* *Jour. de Phys.* liii. 92.

is mixed with hydrogenated sulphuret of potass or ammonia, it combines with the sulphur, leaves the alkali, and the black sulphuret becomes red in a few days. We may conclude, in all probability, according to the original theory of Berthollet, that æthiops mineral and cinnabar differ from each other principally in the first compound containing sulphurated hydrogen.

Sulphuret of copper.

2. Sulphuret of copper is composed, according to the analysis of Mr Proust, of 82 copper
18 sulphur

100

This sulphuret is capable of combining with an excess of sulphur, and in this state it is often found native. It is of a deep blue or violet colour, and resembles indigo rubbed with a polished body. It is composed of about
85 sulphuret of copper
15 sulphur

100

And of course contains 0.30 of sulphur*.

Sulphuret of iron.

3. Sulphuret of iron, according to the analysis of Mr Proust, is composed of 40 iron
60 sulphur

100

Pyrites.

It has been hitherto supposed that pyrites is a compound of sulphur and the black oxide of iron; but Mr Proust has ascertained, that when heated it allows 0.20 of sulphur to separate, and that 0.80 of common sulphuret remains behind. Hence it follows that pyrites

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[*] *Jour. de Phys.* liii. 95.

is composed of 80 sulphuret of iron
20 sulphur

100

Of course it contains no less than 0.68 of sulphur. It is therefore a sulphuret combined with an additional dose of sulphur. This additional dose differs in different species of pyrites *.

Sulphuret of arsenic.

4. When sulphur is heated with arsenic acid, or the white oxide of arsenic, sulphurous acid gas is exhaled, and the mixture melts into a vitreous red substance, which is a sulphuret of arsenic; for it may be formed by melting together sulphur and arsenic. It has been supposed that orpiment, or the yellow sulphuret of arsenic, is a compound of sulphur and the oxide of arsenic: but Mr Proust has ascertained that when heated it melts without emitting any gas, and assumes the appearance of red sulphuret. Hence it follows that the arsenic in this compound also is in the metallic state †.

II. Of Nickel.

Mr Chenevix precipitated nickel from an impure acid solution by ammonia, filtered immediately, and allowed the ammoniacal solution of nickel to stand some days in a well-stopped phial. A bluish precipitate subsided, which was also separated. The liquor was now evaporated, and the oxide of nickel properly washed and reduced in the usual manner. The nickel thus obtained was of a pale red colour, its hardness was considerable, and its fracture granular and uneven. Its specific gravity was 7.3806, and it was not magnetic, nor

Properties of nickel.

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* *Jour. de Phys.* liii. 89.

† Ibid. p. 94.

It is not magnetic.

had it the smallest effect upon the magnetic needle [*]. Hence we must conclude that the magnetism of common nickel is owing to the iron that it still contains, and probably this is the case with cobalt. Thus a portion of iron, so small as not to be detected by the best chemical tests, when it is combined with nickel is susceptible of communicating magnetic properties to the whole mass as strong as if the whole were composed of steel; a fact still more important, and certainly more extraordinary, than if nickel and cobalt were themselves magnetic.

To obtain pure nickel, the rules laid down in Vol. IV. p. 166. are to be followed; but the iron present must be oxidated to a maximum, the ammonia should be perfectly caustic, and it is proper to allow the ammoniacal solution to remain till some nickel has precipitated [†].

III. Of Columbium.

Mr Hatchett has lately discovered a new metal in an iron ore from America, and has given it the name of *columbium*. The analysis itself is not yet published, but Mr Nicholson has inserted an abstract of the experiments in the first number of his octavo Journal.

Discovery.

The mineral was sent to Sir Hans Sloane by Mr Winthrop of Massachusets. It is heavy, of a dark grey colour, and has some resemblance to chromat of lead. The mineral acids have but little effect on it; the sulphuric indeed dissolves a little iron. When fused with carbonat of potass, and then washed in pure water, part of it is dissolved: muriatic acid dissolves another por-

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[*] Nicholson's *Journal*, v. 288.

[†] Chenivix, Ibid.

tion. By treating it alternately with carbonat of potass and muriatic acid, it is completely dissolved. The acid holds iron in solution; the alkali is combined with a peculiar metallic acid, to which the name of *columbic* has been given. The mineral therefore is a columbat of iron. It is composed of about 75 columbic acid
25 oxide of iron

100

Composition of the ore.

Nitric acid precipitates columbic acid from its combination with potass in the form of white flakes.

Properties of columbic acid.

This acid precipitate seems to be insoluble in water, but it reddens litmus paper. It is insoluble in nitric acid, and remains perfectly white; but both muriatic and sulphuric acids dissolve it.

When these solutions are saturated with potass, columbic acid precipitates in white flakes. Triple prussiat of potass occasions an olive green precipitate; the tincture of nutgalls a deep orange precipitate: when the solution of columbic acid in sulphuric acid is diluted with water, a white precipitate appears, which when dried becomes first blue and then grey. Zinc precipitates a white powder from the same solution.

Columbic acid combines with potass and soda, both by the dry and humid way. It expels carbonic acid, and forms with potass a glittering scaly salt, which has much the appearance of boracic acid. It does not combine with ammonia.

Acids separate columbic acid from the fixed alkalies; and when added to excess do not redissolve it unless heated, and even when heated nitric acid has no effect. The same thing takes place when an excess of alkali is added to the acid solutions.

Book II.

Hydrosulphuret of ammonia, added to the alkaline solutions, forms a chocolate coloured precipitate. Prussiat of potass and tincture of galls produce no effect till an acid is added; and then the usual olive green and orange precipitates appear.

The acid and alkaline solutions are colourless. Columbic acid does not combine with sulphur in the dry way. It forms a purplish blue glass with phosphat of ammonia. It appears to be of extremely difficult reduction *.

BOOK II.—CHAP. III. OF OXIDES.

SECT. I. CARBONIC OXIDE, Vol. I. p. 474.

THE nature of this gas has been examined by Morveau, Berthollet, Fourcroy and Thenart, Desormes and Clement. Their experiments coincide with those of Mr Cruickshank: but several additional properties have been ascertained, which I shall here enumerate.

The French chemists were led to examine the nature of carbonic oxide gas, by an excellent paper of Dr Woodhouse on the gases evolved by distilling moistened charcoal, and mixtures of charcoal and metallic oxides. He obtained a great quantity of inflammable gas, and thus confirmed the experiments of Dr Priestley. The French chemists ascertained, as Mr Cruikshank had done before them, that this gas is composed of carbon and oxygen. Desormes and Clement have subjected it to a very complete investigation.

How carbonic oxide is procured.

They obtained it, 1. By exposing moist charcoal to a

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* Nicholson's 8vo *Journal*, i. 32.

red heat—2. By heating mixtures of charcoal and metallic oxides to a red heat—3. By heating mixtures of charcoal and the earthy carbonats—4. By passing carbonic acid repeatedly over red hot charcoal. It is formed also during the distillation of several vegetable bodies, and during the combustion of a mixture composed of three parts of nitre and one part of charcoal.

Its composition, as ascertained by these chemists, agrees almost exactly with the result of Cruikshank's experiments, after we correct some fundamental errors which have slipt into their calculation. They have rendered it probable that the proportion of its carbon varies considerably.

Properties of it.

It is exceedingly noxious; animals die in it instantly: when breathed, it produces instant giddiness and fainting.

Neither light, nor heat, nor electricity, have any effect upon it. It is not altered by being made to pass through a red hot-tube.

When equal quantities of this gas and hydrogen are passed through a red-hot glass tube, the tube is lined with a fine black enamel of charcoal, water is formed, and an excess of hydrogen makes its escape. If a bit of iron be put into the tube, it is oxydated but not converted into steel.

Neither azotic gas nor sulphur have any action on it, even when assisted by heat. It dissolves a little charcoal and increases in bulk. It dissolves phosphorus, and acquires the property of burning with a yellow flame. The alkalies have no effect on this gas. It is not altered when passed with ammonia through a red-hot tube. When the red oxide of mercury is heated in it, a commencement of reduction takes place.

Neither sulphurous, nitric, nor muriatic acids, alter it when passed with it through a red-hot tube. Four parts of oxy-muriatic gas left with one of carbonic acid gas decompose it completely; carbonic acid is formed, and a substance like wax makes its appearance.

Nitrous gas has no effect on it. When mixed with sulphurated hydrogen gas, and passed through a red-hot tube, sulphur is deposited, and sulphurated hydrogen gas remains mixed with carbonic oxide gas *.

SECT. II. OF WATER, Vol. I. p. 477.

Weight of water at 40°.

FROM the experiments of Lefevre Gineau, performed with great care, in order to ascertain the weight of the kilogramme, it follows, that at the temperature of 40°, at which temperature the density of water is a maximum, a French cubic foot of distilled water weighs 70lbs. and 223 grains French = 529452.9492 grains troy †. Consequently an English cubic foot at the same temperature weighs 437102.4946 grains troy, or 999.0914161 ounces avoirdupois.

BOOK II.—CHAP. IV. OF ACIDS, Vol. II. p. 1.

TWO additions have been made to our knowledge of these bodies. 1. Sulphuric acid has been analysed by Mr Chenevix—2. Sebacic acid has been examined by Mr Thenart.

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* *Ann. de Chim.* xxxix. 26.

† *Jour. de Phys.* xlix. 171.

I. Sulphuric acid, Vol. II. p. 9.

Sulphuric acid.

From the experiments of Mr Chenevix, it appears that sulphuric acid is composed of 61.5 sulphur
38.5 oxygen

100.0 *

II. Sebacic acid, Vol. II. p. 160.

Sebacic acid,

It has hitherto been supposed that sebacic acid is of a very volatile nature; that it has a strong smell; and that it is the cause of the suffocating fumes which appear during the distillation of fat. But Mr Thenart has proved, that hitherto either acetous acid, which is formed during the distillation of fat, or muriatic acid separated from the impure potass employed, has been mistaken for that acid; and that pure sebacic acid had not been examined by chemists previous to his experiments. Pure sebacic acid may be obtained by the following process.

How procured.

Distil hog's lard, wash the product with hot water, separate this water, and drop into it acetite of lead. A flaky precipitate appears, which is to be washed and dried, mixed with sulphuric acid, and heated. A melted substance analogous to fat swims on the surface, which is to be carefully separated. This substance is *sebacic acid.* It may be dissolved in hot water, and on cooling crystalline needles are deposited. This acid may be obtained also by evaporating the water employed in washing the product of distilled hog's lard. Or this water may be saturated with potass, and afterwards precipi-

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* *Phil. Mag.* xi. 116.

tated with acetite of lead as above. Its properties are the following.

Its properties.

It has no smell, its taste is slightly acid, and it reddens the tincture of turnsole. When heated it melts like tallow. It is soluble in cold, but much more soluble in hot water. Boiling water saturated with it becomes solid on cooling; alcohol also dissolves it abundantly. It crystallizes in needles; but by proper precautions it may be obtained in long, large, and very brilliant plates.

It occasions a precipitate in the acetite and nitrat of lead, the nitrat of silver, the acetite and nitrat of mercury. It forms peculiar salts with the alkalies and earths. It does not render lime water, barytic, or strontitic water turbid. Sebat of potass has little taste, does not attract moisture from the air; and when sulphuric, nitric, or muriatic acid is poured upon it, sebacic acid is deposited: when its solution is concentrated and mixed with any one of these acids it becomes solid *.

Besides sebacic acid, a considerable portion of acetous acid is also found in the water which has been employed to wash the product of distilled fat. This acid may be obtained by saturating the water with potass, evaporating to dryness, adding sulphuric acid and distilling; the acetous acid passes over into the receiver.

The acrid fumes which appear when fat is strongly heated, are not acid, but consist of the fat itself somewhat altered †.

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* Nicholson's 8vo *Jour.* i. 34.

† Thenart, ibid. p. 36.

PART I.—BOOK II.—DIVIS. II. CHAP. III. SALTS.

GENUS I. SULPHATS. Vol. II. p. 258.

Sulphat of barytes.

FROM the experiments of Mr Chenevix, it appears that sulphat of barytes is composed of

23.5	sulphuric acid
76.5	barytes
100.0 *	

This does not differ much from the estimation of Thenart.

Sulphat of Lime, Vol. II. p. 265.

Sulphat of lime.

THE experiments of Mr Chenevix give the component parts of this salt in the following proportions

57	sulphuric acid
43	lime
100 †	

This agrees nearly with the estimation of Kirwan.

Salts of Antimony, Vol. III. p. 70.

Method of preparing James's powder.

MR CHENEVIX has given the following easy formula for preparing *James's powder*, or what I have called after Dr Pearson, phosphat of lime-and-antimony.

Dissolve in a minimum of muriatic acid equal parts of white oxide of antimony and of phosphat of lime, and pour the solution *into* a sufficient quantity of dis-

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[*] *Phil. Mag.* xi. 116.

[†] Ibid. p. 115.

Book II.

tilled water, containing pure ammonia in solution. The powder precipitates [*].

Mr Chenevix considers this powder as merely a mechanical mixture. But his reasoning is not quite conclusive; for the acidulous oxide of antimony, which is often employed, has many acid properties; and though it refuses to combine with phosphoric acid, it may unite as an acid with phosphoric acid and lime: and this in fact seems to be the case in most of the triple compounds into which the oxide of antimony enters.

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[*] *Phil. Mag.* xi. p. 110.

I N D E X.

The Numerals denote the Volume—the Figures the Page.

FINIS.

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ERRATA.

Vol. I. p. 111. line 25. After “manner,” insert “as that of gold.”
p. 209. line 19. For “The white oxide may be obtained by sulphuric or nitric acid, or the black oxide of manganese, and adding a little sugar,” *read*, “The white oxide may be obtained by dissolving the black oxide of manganese in sulphuric or nitric acid, and adding a little sugar.”
p. 245. line 14. For “most” *read* “least, and for “least” *read* “most.”
p. 278. line 17. Dele the comma after “however.
p. 286. line 20. Insert “the” after “greater.”
p. 294. line 23. For “makes” *read* “make.”
p. 347. line 2. For “*Micographia*” read “*Micrographia*.”
p. 384. line 6. After “publications” insert a semicolon, and dele the comma after “proved.”
p. 440. line 23. For “lime” *read* “magnesia.”
p. 452. line 12. For “hyacinth” *read* “emerald.”
p. 463. line 1. after the Table. For “alumina” *read* “silica.”
p. 474. line 8. For “this Book” *read* “the First Book.”
p. 475. line 24. For “oxide” *read* “acid.”
p. 476. line 18. For “1.55” *read* “1.54,” and for “3.86” *read* “3.85.”
p. 503. line 20. For “oxides” *read* “acids.”

Vol. II. p. 8. line 6. For “acid” *read* “oxygen.”
p. 51. last line of the Table. For “2.1040” *read* “1.1040.”
p. 63. line 13. For “purest” *read* “strongest.”
p. 180. line 24. For “volability” *read* “volatility.”
p. 201. line 4. For “*vitroli*” read “*vitrioli*.”
p. 205. bottom. For “water” *read* “air.”
p. 315. line 15. For “soda” *read* “potass.”
p. 317. line 11. For “zero” *read* “28.5°.”
p. 318. line 5. For “lime” *read* “magnesia.”
p. 448. line 10. For “this science” *read* “the science.”

Vol. III. p. 254. line 10. For “have denoted” *read* “denote.”
p. 370. at the bottom of the page. For “zero” *read* “28.5°.”

Fig. 26.

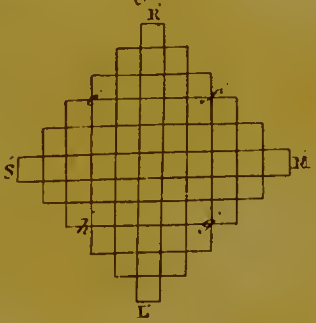

Fig. 27.

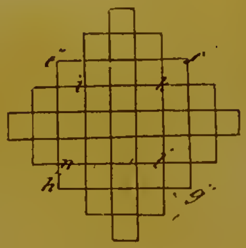

Fig. 28

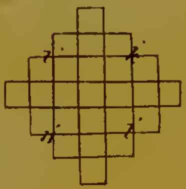

Fig. 29.

Fig. 32.

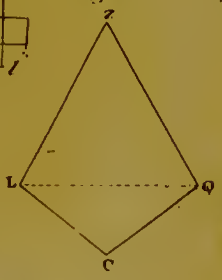

Fig. 30.

Fig. 37

Fig. 35.

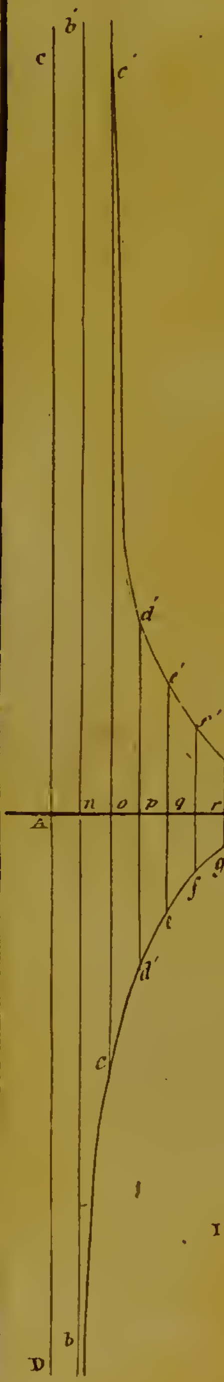

Fig. 38.

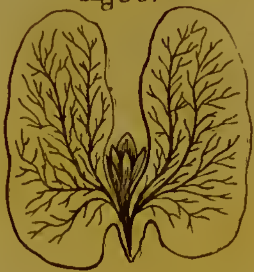

Fig. 31.

Fig. 33.

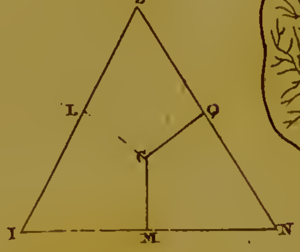

Fig. 36.

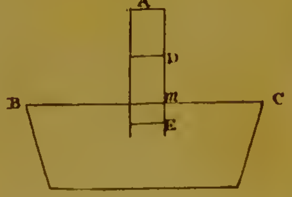

Fig. 34.